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No. 4—MILLING FIXTURES

CONTENTS

Elementary Principles of Milling Fixtures, by E. R. MARKHAM - - - - - - - - - 3

Examples of Milling Fixtures - - - - - 26

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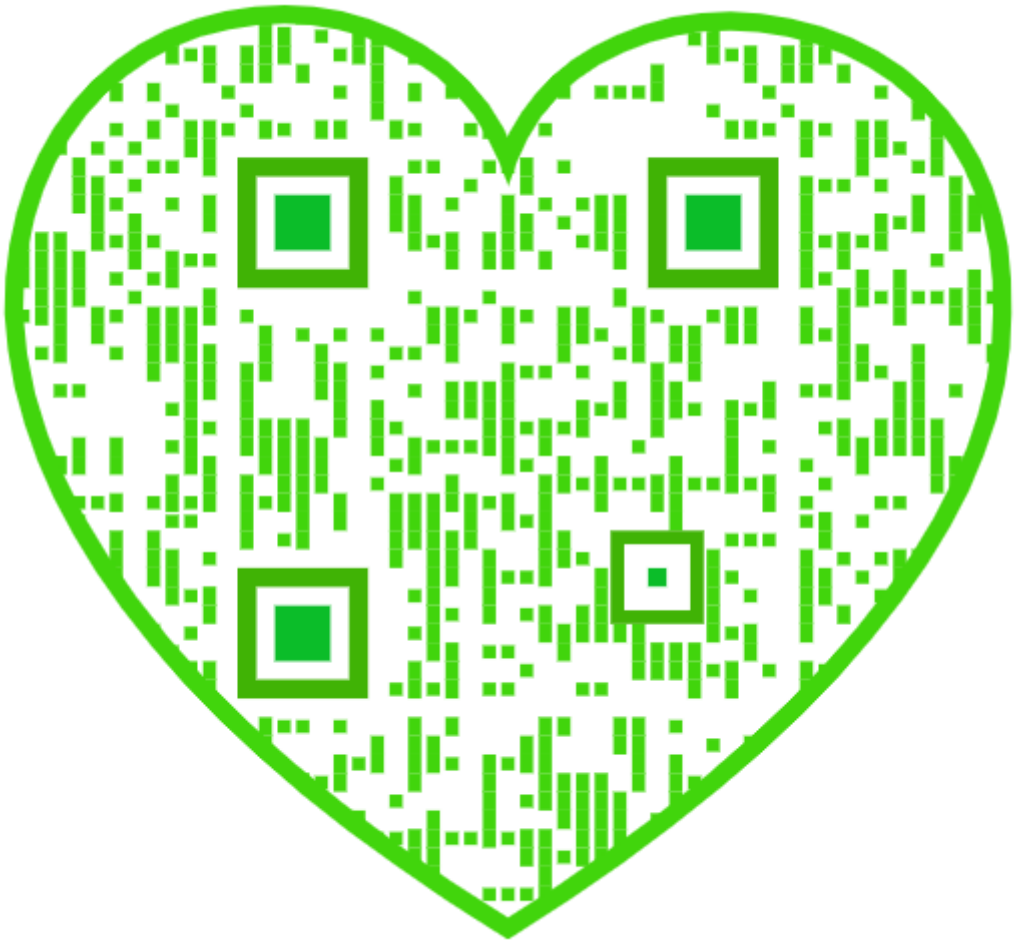

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CHAPTER I.

ELEMENTARY PRINCIPLES OF MILLING MACHINE FIXTURES.

The principal consideration, when designing fixtures that are to be fastened solidly to the table of a milling machine, should be to have the fixture firm enough to admit working the machine and cutter to their limit of endurance. In fact, the fixture should be stronger than the machine itself, and able to resist any possible strain that the cutter can exert. While fixtures should be strong, the movable parts should be so made as to be easily manipulated. All bearing and locating points should be accessible to facilitate the removal of chips and dirt. The action of the clamping devices should be rapid, so that no time is lost in manipulating them.

The Milling Machine Vise—False Vise Jaws.

The first fixture to consider is the milling machine vise, which has a stationary and a movable jaw, against which are placed removable jaws, held in place by means of screws. The stationary-removable jaw generally has connected with it any shelf, pins, or means for locating the pieces to be machined. The reason for attaching them to this jaw is that this portion of the vise is not movable, and is, or should be, stiff enough to resist without springing any pressure that may be exerted by means of the crank and screw. The jaw attached to the movable slide part of the vise, on the contrary, is liable to alter its location slightly under strain, especially when the vise becomes worn.

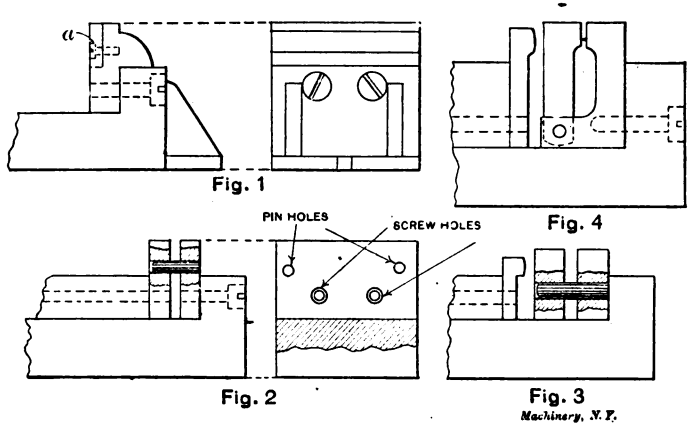
For some purposes, where but a few pieces are to be milled, or where the character of the pieces is such that there is not much liability of the jaws wearing, and thus affecting the accuracy of the pieces, it is safe to make the jaws of cast iron. If, however, there is a considerable strain on the jaws, it is advisable to make them of steel and harden them. For most purposes, jaws made of a good grade of machinery steel and properly case-hardened answer as well as those made from tool steel, and cost only a fraction as much for stock.

If possible, the piece to be machined should be held in the jaws below the level of the top of the vise in order to avoid springing the jaws out of a vertical position, as would be the case if the piece were above the level of the top of the vise. Occasionally pieces are so shaped, however, that they have to project considerably above the top of the vise jaws, in which case the jaws may be made with a rib which extends over the top of the vise and rests on the piece, as shown in Fig. 1. This furnishes a brace and prevents the springing that would prove harmful to almost any piece of work that it would be safe to hold in a vise while milling. As it would prove quite expensive if

34789

many jaws of this style were made from steel, they may be made from cast iron, and a plate of steel placed where the work is to rest, as shown at *a*, Fig. 1. After the steel plate has been cut to shape and the locating device attached, the jaw may be hardened. If the devices mentioned are pieces which must be attached to the jaw, or pins which enter holes in it, they must be removed when the jaw is hardened.

At times it is necessary to hold pieces so that they rest on shelves on each jaw, or are located by pins in both the stationary and movable jaw. Generally speaking, it is advisable to construct special fixtures for such pieces, provided the degree of accuracy and the number of pieces warrant the outlay. However, if the pieces must be held in jaws in the vise, some method should be found to prevent the movable jaw



Figs. 1 to 4. Special Jaws for Milling Machine Vise.

from rising when pressure is applied, in the operation of "tightening up." If the jaws are reasonably thick, large pins may be used, one near each end of the jaw, as shown in Fig. 2. These pins must be forced solidly into one jaw and fit closely in the other. Another method which works nicely is shown in Fig. 3. In this case the movable jaw proper is connected with the stationary jaw by means of pins, or a slide of different design. It is not, however, attached to the movable slide of the vise, but a hardened piece of steel is attached to this and bears against the movable part of the jaw. Many other forms are made, one of which is shown in Fig. 4. The front portion hinges at the bottom, and is pressed against the work by a movable slide. In all such holding devices, however, chips are liable to get between the various parts, decreasing their accuracy.

When making any form of holding device, it is necessary to provide a place for the burrs that are a result of previous operations, unless they are removed by a process of filing or grinding. In many cases these burrs will be removed by future operations if it is possible to provide a place for them so that they will in no way affect the accuracy

of the piece. For this reason milling machine jaws and other fixtures are cut away or recessed in places to allow the burrs a place in which to drop, as shown in Fig. 5 at *A*. At *B* a piece of work is shown with the burr mentioned.

Provisions for Removing Chips.

It is the custom in most shops to provide a liberal supply of oil, or other lubricant, for cutters when milling work that requires lubrication. In many cases this fluid is used to wash out the jaws or fixtures after removing a piece of work. As this supply is used over and over, however, it is liable to become thick and gummy, and apt to prove harmful rather than helpful, unless the operator watches his fixtures closely. In some shops compressed air is used to blow chips from the working surface, and in many cases "works like a charm." On certain jobs nothing seems so effective as the hand and finger method for cleaning the surfaces of the fixtures.

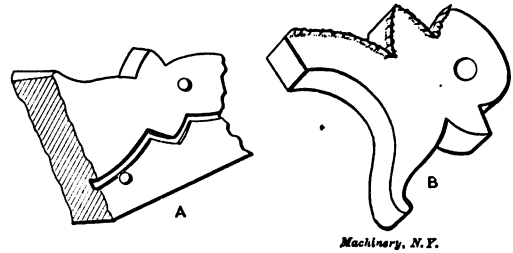


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Fig. 5. Arrangement of Fixture or Vise Jaw to Accomodate Burr

One example of the necessity of taking account of the question of chips, taken from actual practice, may give this matter its full emphasis. This example also shows how at times it is necessary to change existing methods in order to accomplish the desired result. A piece of work consisting of a flange, as shown in Fig. 6, was provided with projecting portions, *a a*, which were to be straddle-milled. The jaws of the vise used to hold this piece had circular grooves, *b b*, Fig. 7, which were thought necessary to properly hold the piece, since the pull of the cutters was in an upward direction; but these grooves made an excellent place for a deposit of chips, and as it was a difficult matter to clean them, and as the operator was working by the piece at a rather low rate, and consequently was not inclined to take too great precautions, the edges of the flanges of the piece being milled became badly scored, and required an extra operation in the turret lathe to remove the marks. To overcome this difficulty, the projecting lips of the vise jaws were cut away and the direction of rotation of the cutters reversed, the overhead belt being changed so that the cutters would run onto the work, thus holding the work securely down on the seating surface of the jaws.

Special Forms of Vise Jaws.

It sometimes happens that the opening in the vise is not sufficient to take in a long piece of work, in which case the jaws may be made

of a form shown in Fig. 8. At other times the vise may be used with the movable jaw of the original form, and with the stationary jaw arranged as in Fig. 9. In this case a flat piece of steel is attached to the outside of the jaw by means of screws which are a snug fit in holes drilled and reamed in both the auxiliary and stationary jaws of the vise. It is apparent that such an arrangement does not allow great accuracy, as the jaw on the end has no backing, and consequently will easily spring, yet there are instances where it answers the purpose as well as a costly fixture. If milling machine vises are drilled for screws that hold jaws in such a manner that the jaws will readily go on any vise, much valuable time may be saved. If we are equipping

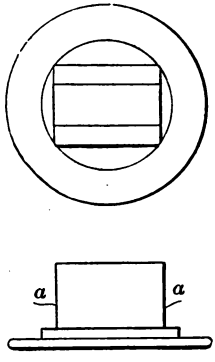

Fig. 6. A Difficult Straddle Milling Job.

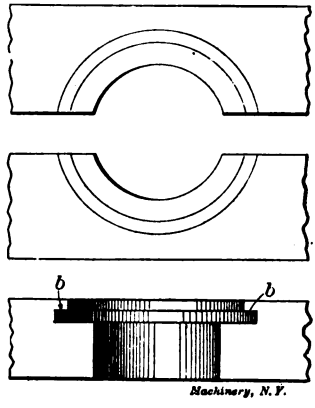

Fig. 7. Arrangement of Vise Jaws to Hold Piece Shown in Fig. 6.

a shop with new machines, this may be readily accomplished, as we may order vises drilled alike and corresponding with some vise already in use, and to which a number of pairs of jaws are fitted.

Cams or Eccentrics for Binding Vise Jaws.

The vises ordinarily furnished with milling machines are opened and closed by means of a screw. Unless it is necessary to apply considerable pressure to the piece being held, this form of vise will not work as quickly as desirable where cheapness of production is a factor. To overcome this objection, vises are made so that the slide may be opened and closed by means of a cam and lever, and unless there is much variation in the sizes of pieces being machined, the cam will cause the work to be held sufficiently firm. The work may be placed in and taken out in this way much more quickly than when a vise operated by a screw is used. In fact, where such a vise will answer the purpose, it will be found as cheap to operate and as satisfactory in results as special fixtures; and the jaws necessary when starting a new job are, as a rule, much cheaper than special fixtures.

When it is necessary to cut in the vise jaws the shape of the piece to be milled, it may be done by milling with the mills to be used on the work, as shown in Fig. 10. The pins, or other appliances for hold-

ing the work, should be added, and are then again removed and the jaws hardened.

Hardening Vise Jaws.

While, as mentioned, such parts of tools as milling machine jaws are ordinarily made from machinery steel, open-hearth steel which does not contain over 25 or 30 points carbon is to be preferred. This may be case-hardened nicely in oil with little or no liability of springing, as the depth of hardness necessary does not call for extreme heat, which causes the steel to go out of shape and also opens the grain of the steel and renders it more liable to become indented should a chip be pressed against the surface. The jaws, if made of this kind of steel, may be packed in the hardening box with a mixture of charred bone and wood charcoal—equal quantities—and run five or six hours after they are red hot. Then they may be removed and dipped in a bath of oil, working them up and down lengthwise in the oil until the red has entirely disappeared, after which they may be lowered to the bottom of the tank and allowed to remain until cold.

If for any reason it is necessary to harden the piece deeper than can be done in the length of time mentioned above, then the red-hot

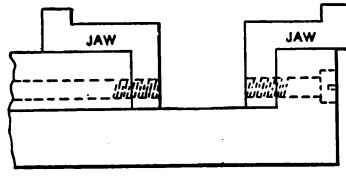

Fig. 8. Off-set Vise Jaws.

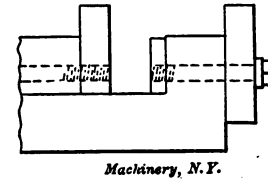

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Fig. 9. Extended Vise Jaw.

jaws may be exposed to the action of the carbonaceous material for a greater length of time. If the jaws are made from the grade of stock mentioned, and are given a low heat, there should be no springing during the hardening process.

Regular Milling Fixtures.

There are many pieces of work that can be machined at a much less cost if a fixture specially designed for the purpose is used. When the number of pieces to be done warrants the outlay, it is generally advisable to pursue this policy. There are other pieces of work that must be held in specially designed fixtures in order to produce a sufficient degree of accuracy, and there are still others that cannot be machined unless such fixtures are provided. The design of such fixtures should always depend on the number of pieces to be machined, and the cost of doing the work. If a fixture is to be used for machining a relatively small number of pieces, then it should be made at as small a cost as possible. If, on the contrary, it is to be used as a permanent fixture for machining the same class of work for an indefinite period, then it should be made in a manner to insure its "standing the racket." Such fixtures should be made very strong and solid, as the cost for stock

and labor is not much greater than when making a too light, more or less useless contrivance.

As cast iron is the material used for the base of most fixtures of this kind, plenty of the material rightly distributed will insure freedom from chattering and uniformity of the product, provided other conditions are right. This additional weight of cast iron does not

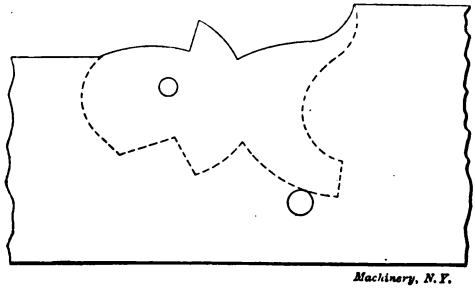

Fig. 10. Vise Jaw made to Correspond to Shape of Work.

materially add to the cost of the fixture. As a rule, cast iron does not prove satisfactory as a surface against which to bed small pieces when milling, and for this reason a surface of steel is generally provided for this purpose.

Examples from Actual Experience.

Fig. 11 shows a milling machine fixture used for milling a leaf for a vernier rifle sight. It is necessary to have the sides, *a a*, of the leaf parallel to the sides of the slot. The base, *b*, of the fixture is made of cast iron, the bottom of which is planed flat. It has a slot cut in it

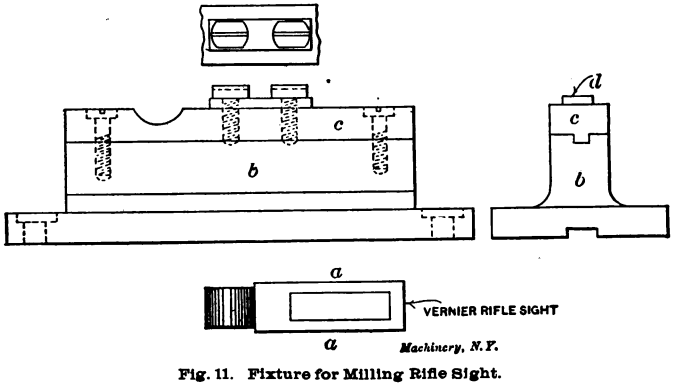

Fig. 11. Fixture for Milling Rifle Sight.

to receive the tongue pieces which fit the tongue slot in the table. A groove is cut in the top surface to receive a tongue on the steel portion, *c*. This is attached to the base by means of screws, after which the projection *d*, for the rifle sight, is milled in the machine used. This insures perfect alignment between the sides of the tongue, *d*, and

the table travel, and in consequence the sides of the leaf are exactly parallel to the walls of the slot when the pieces are milled. In the case of this particular piece of work it was found necessary to provide a somewhat complicated contrivance to hold the leaf down onto the fixture while milling, as the cut was rather heavy, compared with the strength of the sides of the leaf. But it was suggested that by reversing the cutters and running them down onto the work, rather than against it, the cutters would be made to hold the work down on the seating surface rather than to tend to raise it. All that was needed then was two screws, the heads of which screwed down

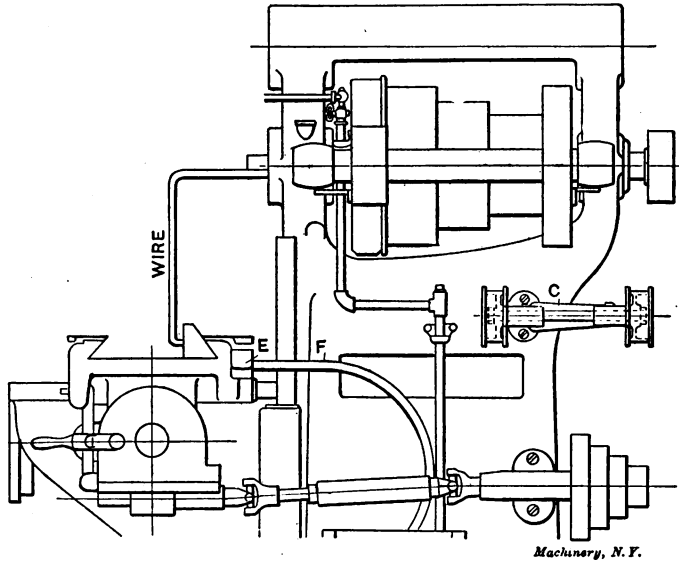

Fig. 12. Testing the Alignment of the Milling Machine Saddle.

onto the leaf. To release the leaf it was necessary to give the screw but a quarter turn, as the opposite sides were cut away to a width a trifle less than the width of the slot in the leaf. The only reason it was necessary to provide the screws was that at the ends of the cut the pressure of the cutters tended to tip the leaf.

Alignment of the Milling Machine Table.

In order to produce good work when straddle-milling on a single-spindle milling machine, it is necessary to have the table travel exactly at right angles to the axis of the spindle. Should it not do so, it will be necessary to either scrape the saddle or swivel the head to get the alignment. The Lincoln type of miller usually has provision for the latter adjustment, but if not, and the saddle must be scraped, it is better to scrape the sliding surfaces which bear against the bed, instead of the table slides, unless the latter should be so badly worn as to need scraping.

The alignment of the saddle of a milling machine may be tested by means of a piece of wire attached to the spindle, as in Fig. 12. In this case the bearing surface to be tested is on a bevel, instead of standing vertical, and therefore a cast iron block is planed to fit the angle portion, the block having a vertical surface for the point of the wire to bear against.

Principle of Gang Fixtures.

Fixtures are many times made to hold two or more pieces of work to be machined at the same time, thus increasing the efficiency of the machine. Fig. 13 represents a fixture used in milling a bolt head flat on opposite sides. The fixture is designed to do away with any inaccuracy that might result from an attempt to mill bolts whose bodies were of varying sizes. For this reason the grooves for holding the bolts are made V-shaped instead of circular. The fixture is so designed as to allow the strain incident to cutting to come against the solid part of the fixture. To insure ease of manipulation, the cam

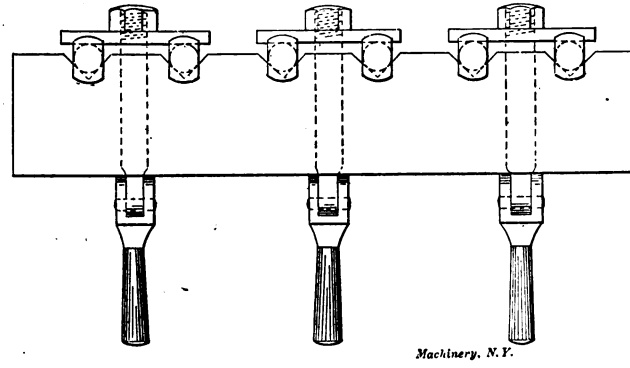

Fig. 13. Fixture for Milling Bolt Heads.

levers, used in clamping the pieces in the fixture, are located in the portion of fixture nearest the operator. Were they located on the opposite side it would be necessary to run the table back far enough to get the cam levers away from the cutters, so as not to endanger the operator's hands. Then again, if located nearer the cutters, they would be covered with chips, thus rendering it necessary to clean them every time before handling. The designer should always have in mind the safety of the operator, not only from a humanitarian standpoint, but also because accidents caused through poorly constructed tools and appliances are extremely costly to the manufacturing concern in whose shops they happen.

Prevention of Springing Action in Fixtures.

It is generally the best practice to have the device used in binding the piece of work to the fixture connected with that part which holds the work, as shown in Fig. 14. If this plan is adopted there is no danger of springing the fixture and thus producing work which is not uniform to gage, as might happen if the design shown in Fig. 15 were

used. If the fixture is extremely heavy and there is a certain amount of error allowable in the gaging, the objection to the method shown in Fig. 15 would not be readily apparent. However, for accurate work it is advisable, when possible, to adopt the method shown in Fig. 14, for it is possible to spring fixtures which are apparently quite strong.

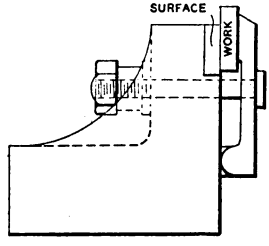

Fig. 14

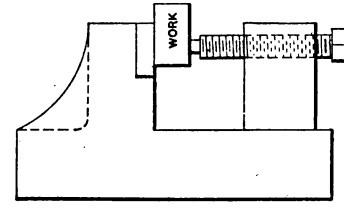

Fig. 15

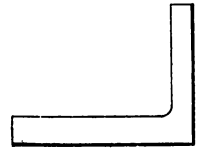

Fig. 16

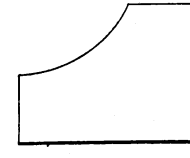

Fig. 17

Figs. 14 to 17. Preventing Springing Action in Vises and Fixtures.

If a fixture is to be made in the form of an angle iron and considerable strain is to be exerted by the operation of cutting, the upright portion of fixture should be made heavy, so as to absorb vibration, and it should be well braced on the back to prevent any tendency to yield under the strain. If such a fixture were made as shown in Fig. 16, the piece of work being machined would be chatter-marked from the vibra-

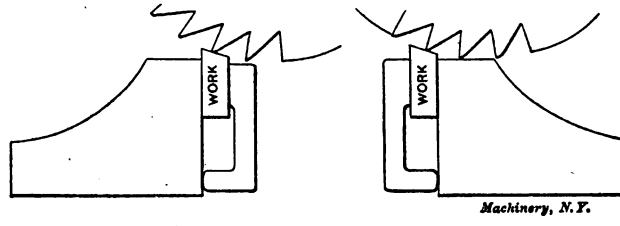

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Fig. 18. Fig. 19.

Proper and Improper Direction of Cut.

tion, and out of true from the yielding of the fixture. If it were made as shown in Fig. 17 neither of these troubles would be experienced, provided other conditions were right. When possible, the pressure of the cutter should always be against the solid part of the fixture, as shown in Fig. 18, rather than against the holding device, as in Fig. 19. One thing that is sometimes overlooked is the inability of the cutter arbor to do the work without springing. Many times cutters are made with holes so small that the arbor cannot transmit the power without springing. If arbors are made for a special job and are to be subjected to great strain, they should be as short as possible.

Fundamental Principles of Milling Fixture Design.

The simplest fixture that will hold the work in a satisfactory manner is, as a rule, the most satisfactory, to say nothing of its lower cost. It is necessary at times, in order to accomplish a certain purpose, to make a complicated fixture, but the more complicated such a tool is. the greater the probability of its getting out of alignment and out of working condition. There is a tendency on the part of many young designers to make elaborate fixtures, not realizing that true success in this branch of business depends on making all machines and tools in the simplest way possible. To be sure, most of the automatic machinery on the market is very complex in design, but the designer uses every effort to simplify where possible, and still have it accomplish the desired result.

While it is absolutely necessary that milling machine fixtures be made in a manner that insures the desired degree of accuracy, yet they should be so designed that the work may be placed in and taken out in the shortest space of time possible, since this item adds very

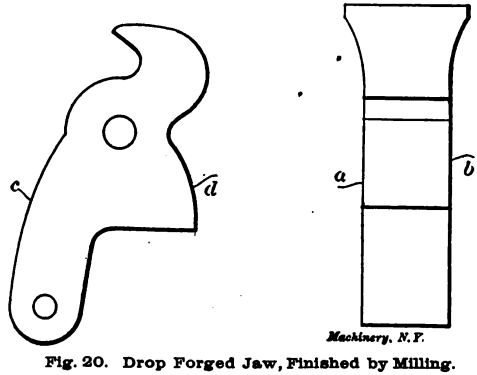


Fig. 20. Drop Forged Jaw, Finished by Milling.

materially to the cost of the article. As it is customary to have the operator run several machines, the greater the length of time necessary to devote to one machine, the fewer machines he can tend.

So far as possible the design should be worked out by always working to, or by, a given surface, or other working point, and in making the fixture the same principle should be adhered to. It is poor practice to change and work from a different working surface unless compelled to do so, as any slight inaccuracy, that in itself might be of little consequence, might affect other vital portions. This same principle should apply to all machining operations.

Examples of Practical Applications.

As an example of what has just been said, let us consider the cutting plier jaw shown in Fig. 20. This jaw was first forged to shape from tool steel under a drop hammer. The side marked *a* was milled first, after which the opposite side was milled. Unless great care were taken when seating in the jaws, the second side milled would not be

parallel with the first. Now, this would not materially affect the finished jaw if one particular side were selected and worked to throughout the various milling operations. The surface *a* was selected as the working surface and was the one placed against the working surface of the drill jig. Then, under normal conditions, the drilled holes would be square with the surface worked from. The same side was also placed against the stationary jaw in milling machine vise when milling the surfaces *c* and *d*. Then, if the jaws were properly made and set in the vise and reasonable care taken to prevent the presence of chips and dirt, the surfaces *c* and *d* would be square with *a*.

A simple method to use when it is required to mill a block perfectly square is to first straddle-mill two sides by holding the block in the jaws of a milling machine vise. The other sides are straddle-milled by holding the piece in the simple fixture shown in Fig. 21, so designed

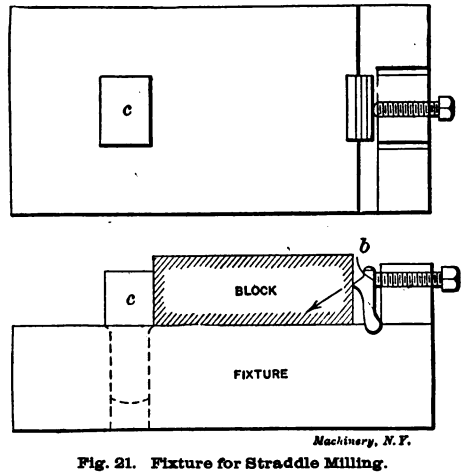


Fig. 21. Fixture for Straddle Milling.

that when the piece is fastened in the fixture, the tendency of the tightening device is to draw one of the sides that were milled at the first operation down onto the seating surface of the milling fixture as shown in Fig. 21. The tilting block *b*, bearing at the bottom, acts in such a manner that when pressure is applied with the screw it forces the work down on the seating surface of the fixture, and against the upright. It might be found necessary when starting to use a fixture of this description to block up under one edge with paper to bring the milled surfaces square with the seating surface, as the spindle and table of the machine might not stand exactly parallel. This must be ascertained by experiment. The parallelism of the two may be tested with a height indicator of the description shown in Fig. 22. However, if it is found necessary to raise or lower the machine the table may not stand in exactly the same relation to the arbor as before moving. Then, again, the arbor may not be exactly true. All these things must be taken into account when testing machines for alignment.

Milling a Bicycle Hub.

Fig. 23 shows a bicycle hub having projections. Through these projections, or ears, are drilled holes to receive the spokes. The equipment of milling machines in the shop where these hubs were to be milled was not sufficient to turn out the required number of pieces, and as it was not deemed wise to increase the equipment, ways were

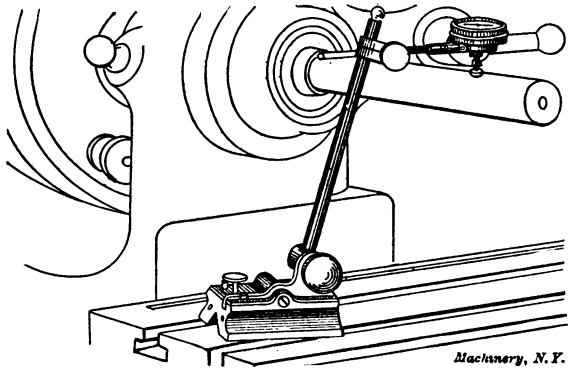


Fig. 22. Testing the Parallelism of Table and Spindle.

devised of doing the additional amount of work on the machines on hand. In order to accomplish this task, it was found necessary to make multiple fixtures.

Two fixtures were made to go side by side on a plate, each fixture to hold a hub. A dog was attached to one end of the hub, the tail of the

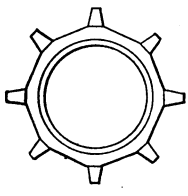
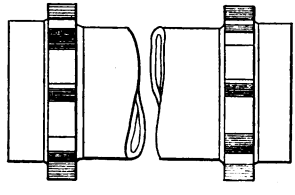


Fig. 23. Bicycle Hub.



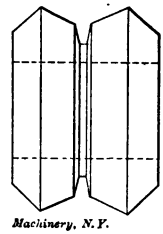


Fig. 24.

dog entering an opening in the plate on the nose of the fixture spindle. On the other end of the spindle was an index plate having around its circumference a number of holes equidistantly spaced, the number of which corresponded with the number of teeth to be milled on the hub. A hardened steel pin entered these holes and thus located the hub. In making fixtures of this character where fine chips can get into the holes, it is advisable to make locating holes straight rather than tapering, since when the holes are tapering there is a strong probability of fine particles getting in the holes on one side of the pin, thus causing the work to be unevenly spaced; but where the hole and pin are straight, if the pin enters the hole, it must necessarily locate

the spindle properly. If the holes and pins are properly ground and lapped, they will retain their size for a long time. In order to facilitate the pin entering the hole the end should be chamfered somewhat.

When milling the job shown in Fig. 23, it occurred to the operator that not only could two hubs be milled at a time, but one could also make each cutter able to mill the spaces between two teeth each time, making a cutter of the form shown in Fig. 24. This shows how fixtures and methods are the results of gradual development, and almost any operation, however well planned, can almost always be still further improved upon.

Milling a Tapered Square End on an Axle or Tool.

In Fig. 25 is shown a fixture used to mill a square on the end of an axle, but with the four sides on a slight taper with the axis of the

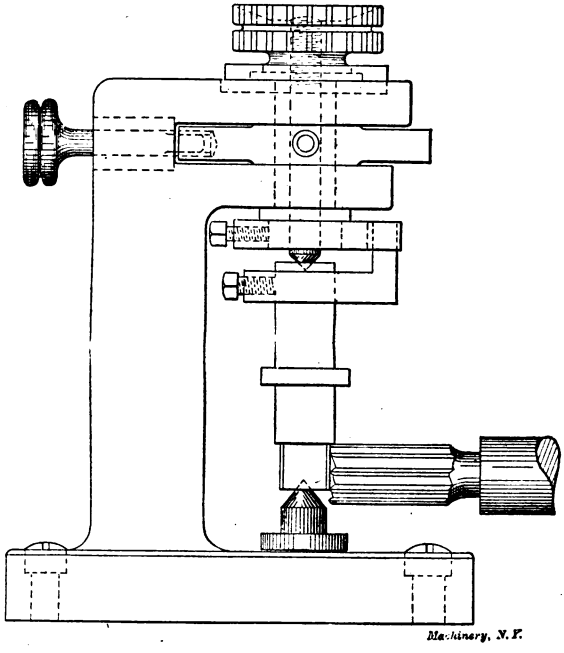


Fig. 25. Fixture for Squaring End of Axle.

axle. On this account it was necessary to use an end mill rather than a face mill, and in order to use an end mill in the ordinary milling machine, the fixture must hold the axle in a vertical position and with the axle standing at the right angle to produce the proper taper. It was found to be impossible to drill the spacing holes in the indexing dial of the fixture with sufficient accuracy by holding it between the centers of the dividing head when the holes were drilled on the universal milling machine, and it was necessary to resort to another scheme. A disk about six inches in diameter was placed between the centers of the universal milling machine, and by means of an end mill

was squared. When tested with a square, it was found that the sides were not exactly square with each other, however, and they were carefully scraped until they were as square as it seemed possible to get them. The disk was then placed on a stud located on an angle plate attached to the face-plate of a lathe. The indexing dial to be drilled was then fastened to the squared disk, and after locating one side of the latter parallel with the face-plate, a hole was drilled and bored in the dial at the proper location, after which the stud was

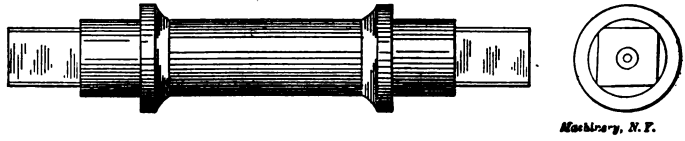


Fig. 26. Axle Milled in Fixture Shown in Fig. 25.

turned so the next side of the squared piece was parallel with the face-plate. By continuing this method, four holes were drilled and bored that were equidistant from each other. These holes were bushed with hardened steel bushings, ground inside and outside, and then forced into the holes. Pieces milled on this fixture, and which were located by this dial, were found so nearly square that no error could be detected when tested with a square. Fig. 26 represents the axle whose ends were milled.

In the previous examples an attempt has been made to avoid using complicated fixtures in illustrating the various methods of doing work, as they would be more confusing, and the simple fixtures illustrate the

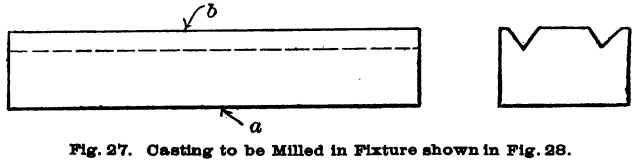


Fig. 27. Casting to be Milled in Fixture shown in Fig. 28.

methods involved as well. There are certain principles which must be observed in designing fixtures of this character. These can be more plainly illustrated when simple fixtures are shown, but the designer may elaborate as much as is necessary to produce a tool adapted to the work in hand.

Fixtures with Adjustable Supports.

We often have to mill articles of cast iron or other metals which are not uniform in size or shape, and which would not locate alike in any fixture, without means of compensation for the irregularities. It has been noticed that columns of milling machines, which weighed 400 or 500 pounds, have sprung out of true when on the planer table by tightening a holding bolt, when the wrench used was an ordinary 6-inch wrench, apparently applied with small force. To secure a good job, it is therefore necessary to block under the work very carefully, and then fasten it securely for the roughing cut; and for the finish cuts the strains on the clamp have to be removed entirely, or nearly so.

If it is possible to spring a large mass of metal in this manner, it is apparent that comparatively weak pieces may be distorted very easily. For this reason, it is necessary many times to provide adjustable supports at the points where the fastening devices are located, and also at points where the pressure of the cutter would have a tendency to spring the piece.

Fig. 27 represents an iron casting, the surfaces of which are to be milled. As castings will distort more or less in cooling, and as they are very liable to alter their shape when the surface "skin" is removed, it is often necessary to provide fixtures with adjustable supports for

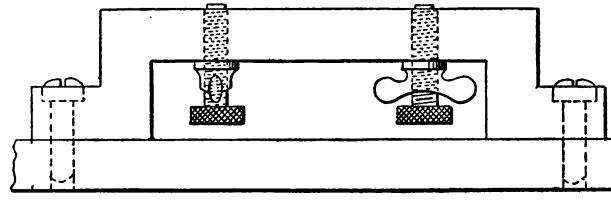


Fig. 28. Fixture for Supporting Piece Shown in Fig. 27.

holding the piece, as shown in Fig. 28. In milling a piece like that of Fig. 27, such a fixture should be used when taking roughing cuts on surfaces *a* and *b*, and the finish cuts on surface *b*.

In the case of work that must be very accurate as to dimensions and truth of finished surfaces, it will be found necessary to finish the surface *a* approximately true by means of grinding or scraping before milling the surface *b* for finish. This is especially true with such work as the knee of a milling machine, as shown in Fig. 29, where it would

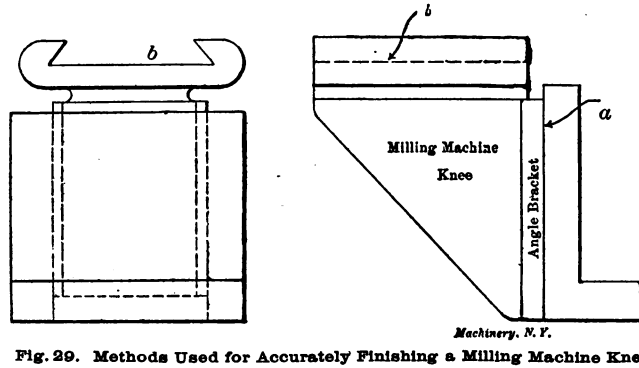


Fig. 29. Methods Used for Accurately Finishing a Milling Machine Knee.

be necessary to rough mill the surfaces *a* and *b* and finish mill *a*. After this, the knee should be "rough scraped" to give it a bearing against the fixture and to prevent it winding or twisting, as would be the case if the surface *a* were not true and were clamped against the fixture. To attempt to scrape these surfaces and get out a wind occasioned by inaccurate milling, owing to one of the surfaces not being flat against the holding device, when the finishing cut was taken over the other surface, would cause much needless expense. While the

above remarks are applied directly to the milling of a milling machine knee, they are equally applicable to any piece of work that must be true, and whose shape or material renders it liable to spring as a result of some machine operation.

There are jobs which require a number of cuts on one side and which must be of a certain *uniform* depth from a given surface. If the pieces are of a uniform thickness they may be held in the usual manner, by having the under side of the piece bear against the seating

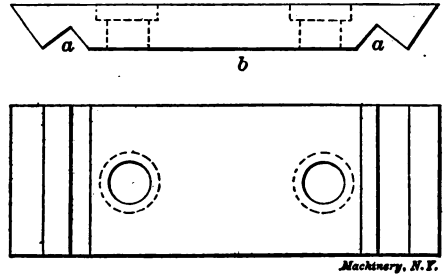


Fig. 30. Work Milled in Fixture Fig. 31.

surface of the fixture and the cuts taken on the upper side. If, however, the pieces are not of a uniform thickness, and the cuts must be of an exact depth, some other method of holding must be employed. Fig. 30 represents a cap used for holding a traveling carriage in place on a knitting machine. The V-grooves *a a* must be of given depth from the surface *b*, and owing to certain conditions it is not practicable to mill that surface at the time the grooves are milled. The distances from the screw holes must also be equal.

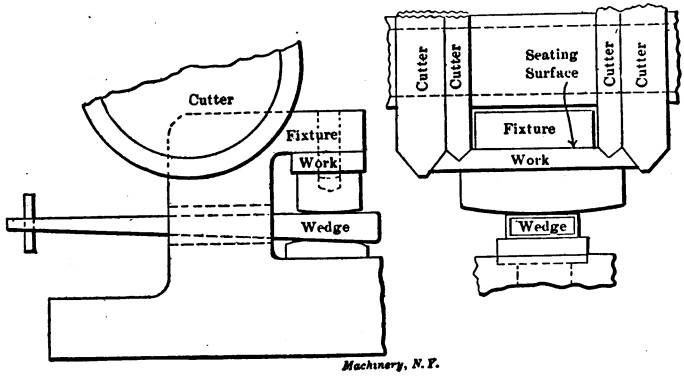


Fig. 31. Fixture for Holding the Piece Shown in Fig. 30, while Milling.

A fixture of the design shown in Fig. 31 was made to hold the cap when milling the V-slots and bevel on ends. It will be observed that it is an inverted fixture and that the surface *b* of the cap, which has been previously milled, rests against an under surface of the fixture. Pins which fit the screw holes in the cap project from the seating surface of the fixture and enter these holes, thus properly locating the cap,

which is securely held against the seating surface by means of a wedge. Between the wedge and cap is placed a block, as shown. When the wedge is driven forward, the block may be removed and the cap taken from the fixture. The pin at the thin edge of the wedge prevents the wedge from being driven entirely out of the fixture.

At times when fixtures of the character mentioned are to be used, it is wise to make them of the style shown in Fig. 32, the cutters being beneath the fixture. In this case, the seating surface being uppermost, it is more easily cleaned than when the fixture shown in Fig. 31 is used.

Bridge Milling.

A method of milling a certain class of work which is not used so extensively as it was a number of years ago, and which is entirely unknown to many mechanics, is known as bridge milling. In some shops work is done on profiling machines which might be done in a satisfactory manner by this method and at a fraction of the cost. The desired shape is produced by means of a form, *A*, which is securely

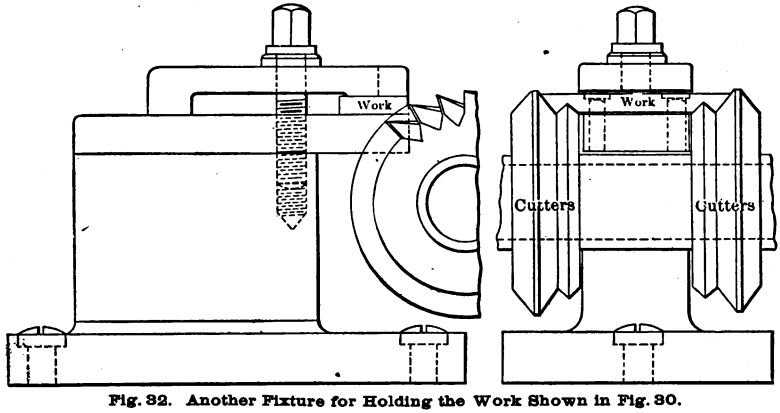


Fig. 32. Another Fixture for Holding the Work Shown in Fig. 30.

fastened to the movable leaf, *B*, of the fixture, as shown in Fig. 33. This leaf is swung between two uprights, *C C*, by means of a heavy steel pin. The base of the uprights is securely fastened to the table of the milling machine by screws. To each side of the saddle, and directly opposite each other, are fastened posts, *D D*, which support the bridge, *E*, reaching across the table. The lower side of the bridge should be but a trifle above the table, say 0.001 inch, so that the table of the machine may prevent it from springing more than that amount when pressure is exerted by the operation of cutting. In the surface of the bridge is cut a slot to receive a hardened steel piece, *K K*, which, being narrow at the top, allows the movable leaf to move in conformity to the shape of form fastened to its under side.

Fixtures of this character may be used many times for milling a number of pieces at once. As an example may be mentioned a fixture for milling the legs of machinists' calipers. These are milled from pieces of square machinery steel to the shape shown in Fig. 34, where

a represents the piece of mild steel cut to length; *b*, after one side is milled to shape; and *c*, after both sides have been milled. Eight pairs of legs are milled at a time, and at a fraction of the cost of drop forgings.

Fig. 35 shows a case of bridge milling the flat portion at the end of a bicycle crank. As in the case of the caliper legs, a double fixture is used and six pairs of cranks milled at a time, milling the right-

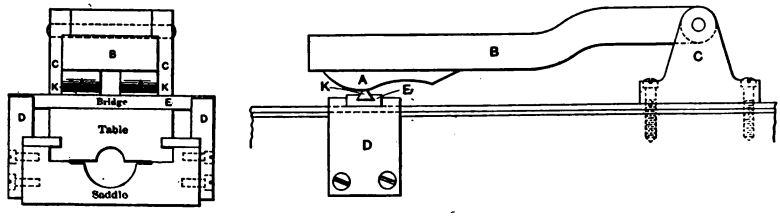


Fig. 33. Principle of Bridge Milling Fixture.

hand crank in one fixture and the left-hand in the other. These are located side by side on the same machine. On account of the unequal quantity of stock removed at the various portions, a slight inaccuracy can be observed, but this is corrected by running the cutters across the work twice at the same setting of the pieces.

In these two examples of bridge milling cited, the milling was done with straight cutters, whose teeth were cut spirally, the helix being right-hand on one cutter and left-hand on the other, to do away with the thrust incidental to long interlocked spiral mills where the teeth of several cutters are of the same hand helix.

Vertical Spindle Milling.

When surfaces are to be machined flat it will be found more satisfactory and quicker, in many cases, to use an end mill of the proper design. The work may be held in a special vise or in an ordinary vise

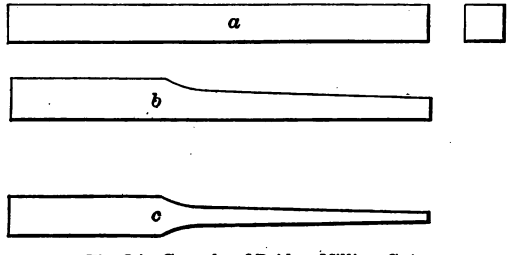


Fig. 34. Sample of Bridge Milling Cuts.

attached to the vertical face of an angle iron, and done in an ordinary horizontal milling machine as indicated in Fig. 36. The best results in vertical milling are obtained by using a vertical spindle milling machine, especially if heavy cuts are to be taken; but unless there is work enough to keep the vertical machine busy, it is, generally speaking, advisable to buy a horizontal machine with a vertical attach-

ment, since it is possible to use the machine either way, as required. The fixtures for holding work when machining by this method will not differ materially from those already described. There are several advantages of vertical over horizontal milling for many classes of work; one very important one is that the surface being milled is usually more plainly in sight in the vertical machine, being turned

Fig. 35. Bridge Milling Cut on a Bicycle Crank.

upward, than in the horizontal, where it would have to be turned inward to the spindle, in order to permit the milling operation to be performed.

Cams or Eccentrics for Binding Work in Fixtures.

Cams are applied to vises and special fixtures in a variety of ways and furnish a rapid means of binding the work in place. At times the cam is very simply made on the end of a piece as shown in Fig. 37. If it is necessary to get considerable length of movement to the slide of the fixture, the cam may be made on a piece having a turned projection on its lower surface which fits in a hole in the base of the fixture. When it has been turned sufficiently to relieve the pressure against

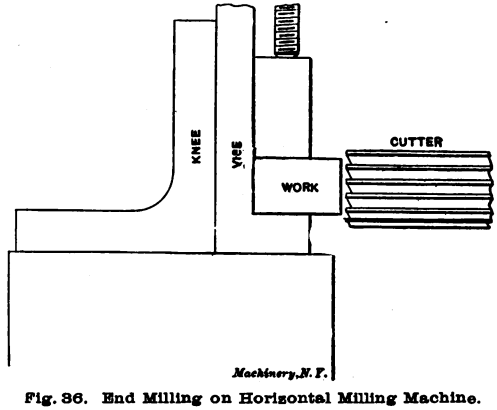


Fig. 36. End Milling on Horizontal Milling Machine.

the slide, the cam may be lifted from the fixture and the slide moved as much as is necessary. After placing another piece of work in the fixture, the slide may be moved against it, the projection on the cam inserted in the hole, and the necessary pressure applied by turning the cam.

Fig. 38 shows a cam which is round in form and has a round projection which enters a hole in the fixture. This smaller projection is eccentric with the larger, in which a hole is drilled and a lever inserted as shown. This, like the previous form, may be removable if desired. Cams of various designs may be employed for holding work, the particular design depending on the piece to be held.

Other Binding Devices.

The method employed for holding work in the fixture depends, of course, on the nature of the work. Unless it is necessary to bind the work more securely than would be possible with a cam, it is not advisable to use a screw, on account of the length of time wasted in

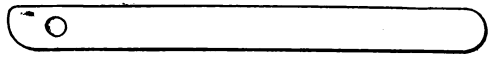


Fig. 37. Simplest Form of Cam Binder.

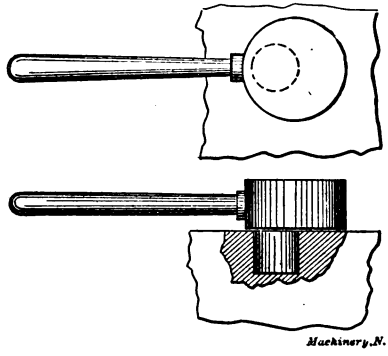


Fig. 38. Eccentric for Binding Work in Fixtures.

turning it back and forth sufficiently to secure or free the work. At times it is *necessary* to use a screw, and it is found possible to save time by the use of a collar of the description shown in Fig. 39. When the nut is turned back part of a turn, the slotted collar may be removed and the work taken out, sliding it right over the nut. After putting another piece in the fixture, the collar is placed on the screw *under* the nut, and the nut tightened to give the desired effect.

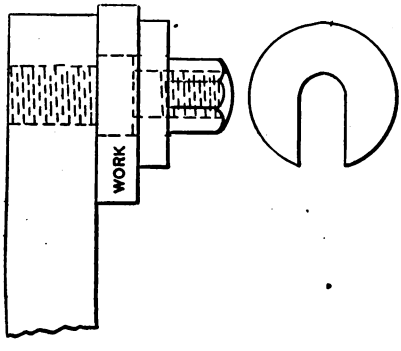
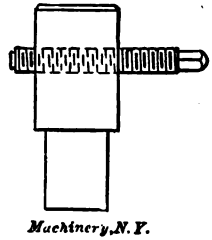


Fig. 39. Slotted Collar for Releasing Work Quickly.



Machinery, N. Y.

Fig. 40. Removable Post or Stud.

Fig. 41 shows a method, some modification of which may be employed to hold work when it would not do to have any screw heads or other devices projecting above the strap. When pressure is applied by means

of the screw, the portion *a* is forced down onto the piece of work. The angle piece is hinged at *b*, as shown. At times it is possible to substitute a cam for the screw, and so lessen the time necessary to operate the device. When forgings or castings are machined, it is sometimes possible to take advantage of the beveled portions occasioned by the draft necessary to get the forging out of the die, or the pattern from the mold. If the amount of bevel ordinarily given is not ample to insure desired results, a sufficient amount may be given when

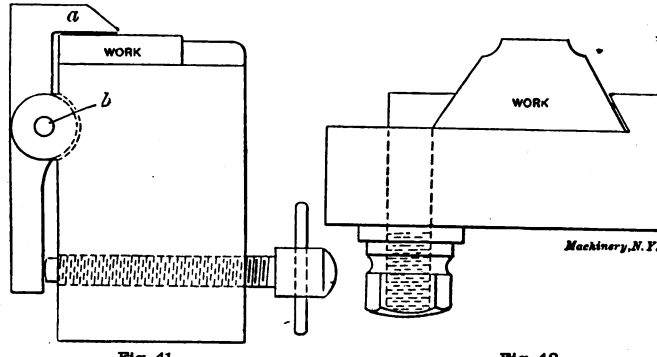


Fig. 41. Fig. 42.
Holding Work where Space is Limited.

the die for the forgings or the pattern is made. Fig. 42 shows a fixture holding a casting by means of considerably beveled edges.

When such a method would bind the work sufficiently strong, it is customary many times to use a screw having a right-hand thread on one end and a left-hand thread on the opposite end. Two applications

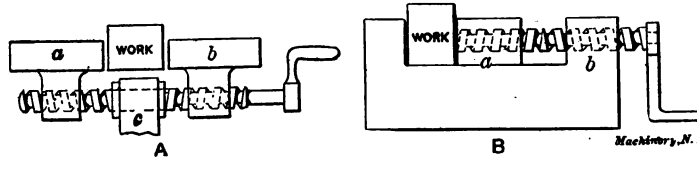


Fig. 43. Differential Screw Movement.

of this principle are shown in Fig. 43; at *A* the screw is held from moving lengthwise by means of the block *c*, and the jaws are moved toward or away from each other by turning the screw. The jaw at the left, *a*, has a right-hand thread, while the right-hand jaw, *b*, has a left-hand thread. This fixture is valuable when it is desirable to mill a slot, or a projection in the center of pieces which vary in width, and where the variation is immaterial. In the fixture *B* the jaw *a* is tapped with a left-hand thread, and the stationary upright, *b*, with a right-hand thread. These threads being square in form may be of coarse pitch, thus causing the slide to move rapidly.

To save time, it is customary at times to locate the binding screw in a removable post, as shown in Fig. 40. When removing the work from the fixture the screw is turned sufficiently to relieve the pres-

sure, and the post lifted out of the hole, after which the work is removed from the fixture, the bearing surfaces cleaned, another piece put in place, and the post again put in the hole, a partial turn of the screw binding it securely. In many instances if a screw were used in a stud securely fastened to the fixture it might be necessary to give it ten or a dozen turns before the work could be removed.

Fig. 45 represents a device used for holding two pieces of work to be machined at the same time. Each piece rests against stationary por-

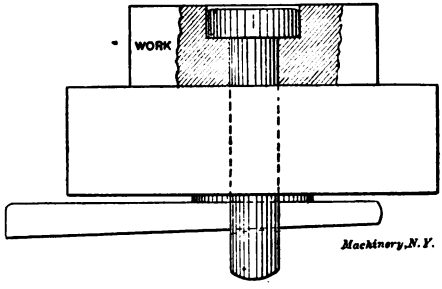


Fig. 44. Holding Work from Below by a Counterbored Hole.

tions *a a* of the fixture, and is held in place by the swinging pieces *b b*, which are hinged at the center, as shown, and are closed onto the work by means of the pointed screw *c* which passes through the stud *d*. This stud can turn in the hole in the fixture, and so allow the point of the screw to swing somewhat to conform to any variation in the thickness of the pieces being held. When pieces have holes through them it is possible many times to take advantage of these in holding the work. Fig. 44 represents a piece of work having on its upper por-

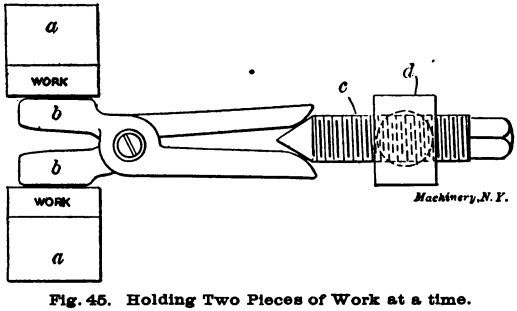


Fig. 45. Holding Two Pieces of Work at a time.

tion a counterbored hole. A pin with a head a trifle smaller than the counterbored portion of the hole extends down through the hole and through a hole in the fixture, as shown. In the small end of the pin is a rectangular hole. Through this is driven a wedge-shaped key, which draws the work solidly onto the seating surface of the fixture.

There are occasions when an ordinary cam would be objectionable and a screw would be too slow, and yet a combination of the two works nicely. Fig. 46 represents such a binding device, which is used

in holding a blank for a spring bow for a machinist's caliper, while the ends are bent in a punch press. When the screw is turned down into the threaded hole in the base, the V-shaped projection under the head passes up the incline on the upper portion of the leaf, forcing it down on the blank. When the projection of the screw reaches the flat portion at the top of the incline, the leaf has forced the blank down solidly to the bending fixture. If the screw is turned more, it, of course, continues to descend and draws the leaf down still more. The advantage of this comination is that if a cam does not pass to its highest point at the end of the throw, it is apt to jar loose if subjected to vibration, whereas the projection under the screw head passing up

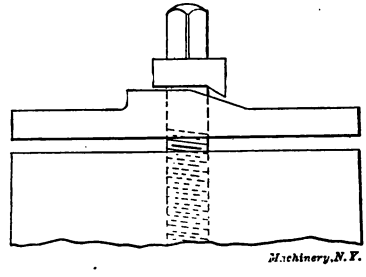


Fig. 46. Combined Cam and Screw Clamp.

the incline acts as a cam, when it rests on the flat portion, and continues to draw the leaf down as the screw goes into the tapped hole. Although a fixture used on a punch press is used to illustrate the idea, the same device may, of course, be applied to fixtures for use on milling machines.

The previous paragraphs are only an outline of the fundamental principles, illustrated by means of simple fixtures and various forms of binding devices. The application must, of course, be left to the individual designer who should always bear in mind that simplicity is always preferable to elaboration, provided the simple device insures the desired result.

CHAPTER II.

EXAMPLES OF MILLING FIXTURES.

In the following a number of examples of milling fixture designs for definite purposes are given. These fixtures are selected as typical of the various kinds of milling fixtures found in machine shops. No attempt has been made to show only fixtures of the most approved designs, but examples indicating general practice have been taken, and attention has been called to the reasons for the special features of each design. The names of the persons who originally contributed the

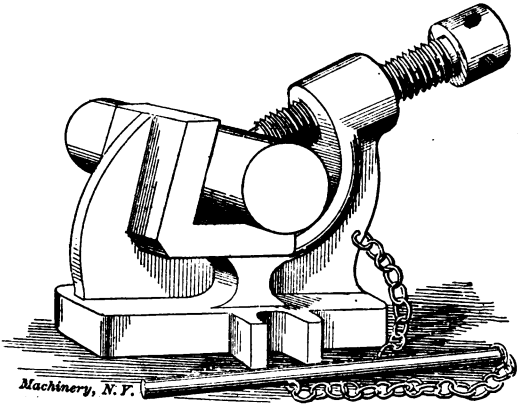


Fig. 47. Vise for Holding Shafts for Keyway Milling.

descriptions of the devices shown, to the columns of MACHINERY, have been given in notes at the foot of the pages, together with the month and year when their contribution appeared.

Vise for Holding Shafts for Keyway Milling.

One of the simplest designs of fixtures for the milling machine presents itself in the form of a special vise for holding short shafts and studs while milling a keyway. Such a vise is shown in Fig. 47. Several advantages over the method of clamping either in an ordinary vise or directly on the milling machine table, are apparent. The clamping bolts, holding the device to the table, are never disturbed while clamping the shafts, and if the fixture once has been set in alignment, it will remain so. Every shaft is clamped exactly alike, the screw forcing the shaft into the Vs bringing every one into exact parallelism, provided, of course, the fixture is accurately set at the start. It is obvious that this device can also be profitably used on the drill press for holding shafts and other cylindrical work for drilling, and with an adjustable arm added for holding a guide bushing for the drill, it would prove efficient as a simple adjustable drill jig.

Fixture for Holding Thin, Flat Work.

It frequently occurs that thin, flat work must be held so that the whole upper surface is free, a milling cut being required to be taken across the entire piece of work. This prevents the use of any clamping devices which bear down upon the work from above, and, if the work is very thin, it does not permit of set-screws entering to bear upon it from the sides, as the diameter of the screws would be greater than the thickness of the work, and consequently project above the surface of the latter. The design of fixtures for the conditions outlined is often a rather difficult matter. A simple solution of the clamping problem is shown in Fig. 48. This cut presents merely one clamp, but it is evident that two or more clamps of the same kind are required for a complete set. The clamp is bolted to the table *H*, with the T-bolt *G*, and the bottom of the casting *A* is planed with a slot for

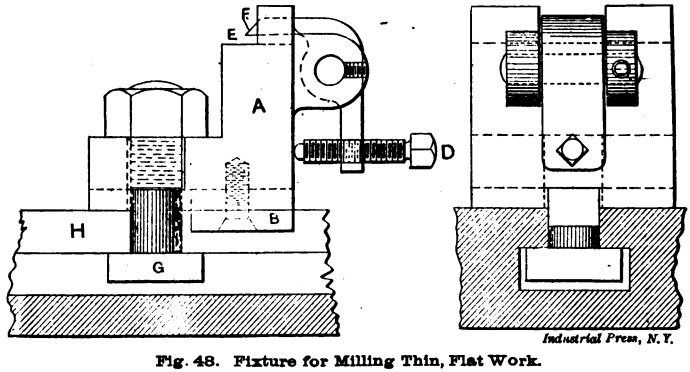


Fig. 48. Fixture for Milling Thin, Flat Work.

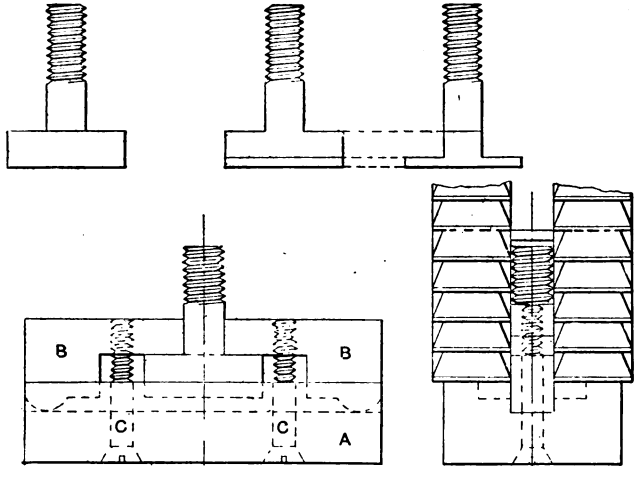
the key *B*. These clamps are used for any flat work which is placed down on the seat *E*; the set-screw *D* is then tightened, thus forcing the steel point *F* downward and into the work. The same operation performed upon the other end securely clamps the work. If the work is long, and so thin that it is likely to spring away from the cutter if not supported in the center, this device should be modified so that the clamps are made integral parts of a fixture body which is planed on top and gives a support to the work for its full length.

Milling Fixture for Bolt Heads.

In Fig. 49 is shown a device for performing a special milling operation, which, however, will illustrate some principles of general milling fixture design. It was required to mill the sides of the heads of screws, such as shown at the upper left-hand corner in the cut, so that they would assume the shape shown at the center of the cut at the top. The fixture shown in the lower part of the cut was designed for this purpose. It consisted of the body *A*, made of mild steel. It was planed all over, and a groove was cut through the body lengthwise, which was made of the same width as the diameter of the body of the screw. A hole was counterbored in the center to a depth equal to

the thickness of the head after being milled. Two clamps *B* were made of tool steel, and hardened to prevent bending. These were machined to fit the groove, thus keeping them from shifting sideways and always in line with the body of the screw to be milled. The two binding screws *C* were also made of tool steel and hardened.

Two 4-inch side or straddle mills, held apart by a collar of a width equal to the diameter of the screw, were used to mill the heads. After placing a screw in the fixture, as shown in the cut, the fixture was placed in a vise on the milling machine, the straddle mills being set to the clamps for position sidewise, and just touching the body of the fixture for the vertical position. With this fixture it was possible to mill the heads with only one cut, and it was found quite



Machinery, N. Y.

Fig. 49. Fixture for Milling Bolt Heads.

satisfactory. While, however, it was possible to mill the screws in this manner so that the result was satisfactory, mechanically, it does not say that this fixture was satisfactory economically. If there were but a few screws to be milled as indicated, then, undoubtedly, a simple fixture like the one shown was preferable. But if there had been a great quantity of screws upon which this operation had to be performed, then a fixture milling one screw at a time, and requiring first the tightening of the two screws *C*, and then the tightening of the milling machine vise, would not have been in place. In such a case a fixture permitting a great number of screws to be clamped simultaneously, and to be milled all at one time, although more expensive to make at first, would in the long run have proved cheaper. A fixture employing this principle is shown in Fig. 50.

The purpose of this fixture is not the same as that of the previous device described, but the principle may be employed for almost any kind of a milling fixture for small work. The fixture shown in Fig. 50

is used on a milling machine for slotting pieces such as shown at *A*, and also for slotting screw heads. The vise jaws *G* and *H* are made out of tool steel, and are left soft; they are placed in a milling machine vise, and the piece *A* to be slotted is placed between the two jaws, as shown. The chamber *C* is a cylindrical hole into which are drilled holes from the side for the cylindrical plungers *D*. The chamber *C* is filled with tallow, and, as the pieces *A* are clamped in between the plungers *D* and the vise jaw *G*, the tallow provides an equalizing effect until all the parts are held equally firm. This means permits pieces of a slightly uneven length to be held securely. The plungers *D* must, of course, be a very good sliding fit in the holes running down to the chamber *C*. The pin *E* simply serves the purpose of locating the piece *A* by entering the hole in its center. The holes *F* are tapped to receive screws holding the jaws to the milling machine vise. Pieces *E* and *D* should be made of tool steel and hardened. When screw

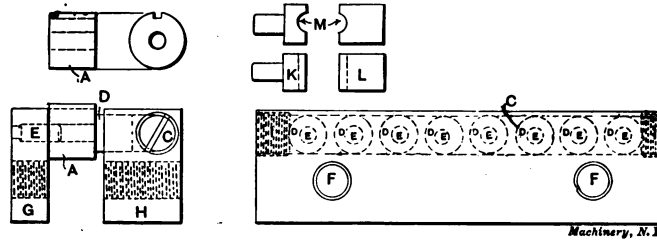


Fig. 50. Equalizing Vise Jaws.

heads are slotted, the parts *K* and *L* are used instead of *D* and *E*. The screws are then held in the semi-circular grooves *M*, the operation of the device being the same as when slotting pieces *A*. The screws *I* in the ends of the circular chamber *C* simply serve the purpose of preventing the tallow from escaping at the ends.*

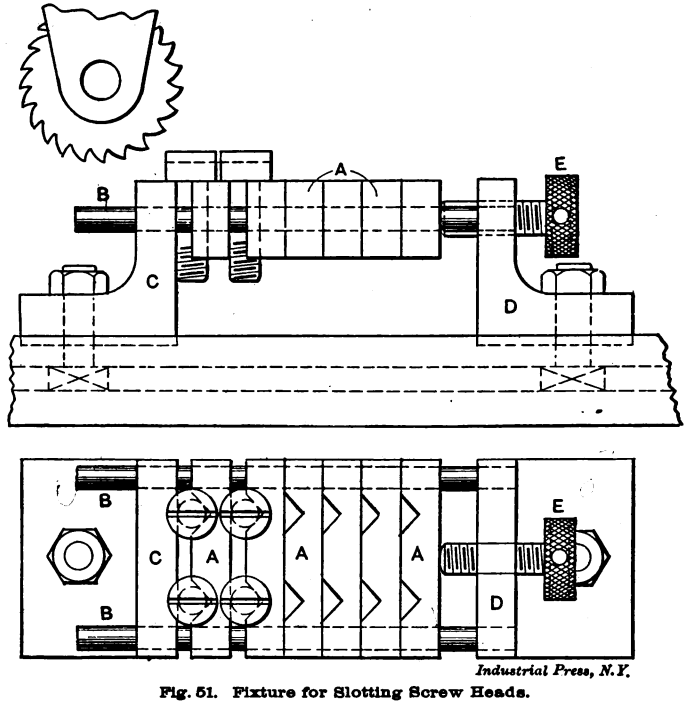
Fixtures for Slotting Screw Heads.

While the fixture in Fig. 50 is, at times, used for slotting screw heads, it is not primarily intended for this purpose. In Fig. 51 is shown a fixture which is designed for this work exclusively, and which, although simple, is an excellent device for holding screws for slotting the heads. It has the great advantage of holding each screw with the same grip, no matter if the diameters are not uniform. It consists of the angle plates *C* and *D*, both having tongues underneath to fit the slot in the milling machine table, and in *D* are fitted the binding screw *E* and the guides *B*, which latter are securely fixed. The guides carry the V-blocks *A*, between which the screws are clamped. The guides slide freely through the holes in the angle plate *C*, and may be made whatever length desired to accommodate the number of V-blocks and screws. If the full capacity of the jig is not required, say only four screws are to be slotted, as shown in the cut, the angle plate *C* is moved toward *D*, so that the binding screw *E* shall be long enough

* S. Oliver, September, 1907.

to clamp the screws. In fact, the arrangement is a most flexible one, and should prove a very satisfactory fixture for any shop.

A rather interesting and suggestive slotting device, the principle of which can be applied to a variety of work where it is necessary to slot many pieces with rapidity, is shown in Fig. 52. The part *A* is a cast iron block, which is bolted and keyed to a hand miller, and *B* is a post which swivels in *A*. At *C* is shown a lever with its fulcrum on the pin *D*. The jaw *E* is hinged to the lever and is held in a closed position by means of the spiral spring on the round head screw *F*, the tension being controlled by lock-nuts. The tool steel plate *G*, on which one



Industrial Press, N.Y.

Fig. 51. Fixture for Slotting Screw Heads.

end of the piece to be slotted rests, is screwed and doweled to the jaw *E*. The spring *H* holds the end of the lever down clear of the cutter, when it is not in operation.

The fixture is first brought clear of the cutter by moving the machine table back; the jaws are then swung out from the machine, bringing the jaw *E* against the pin *I*, which compresses the spring on *F* and thus separates the jaws, so that the piece to be slotted can be put in between the six locating pins. The pressure being then removed from the spring allows the latter to bind the piece securely in place. The lever is then swung so that the jaw *E* comes up against the pin *J*, and the lever itself rests on stop *K*. The table is then fed forward, bringing the piece against the bottom of the cutter, which slots it to the

desired depth. The piece is released by a reversal of these operations. This fixture has proved satisfactory, as it is possible when the machine is ready for operation to turn out 300 pieces per hour. The principle of this fixture could be used for slotting screws.*

In Fig. 53 is shown another device for slotting screws. This is more elaborate, and permits of a continuous operation, the operator placing the screws to be slotted in the fixture simultaneously with the slotting of the screws previously put in. At *A* and *B* are shown two rings of machine steel, case-hardened, with holes drilled on their peripheries suitable to grasp the work to be slotted. The number of holes will vary according to the speed at which the fixture is run and the work

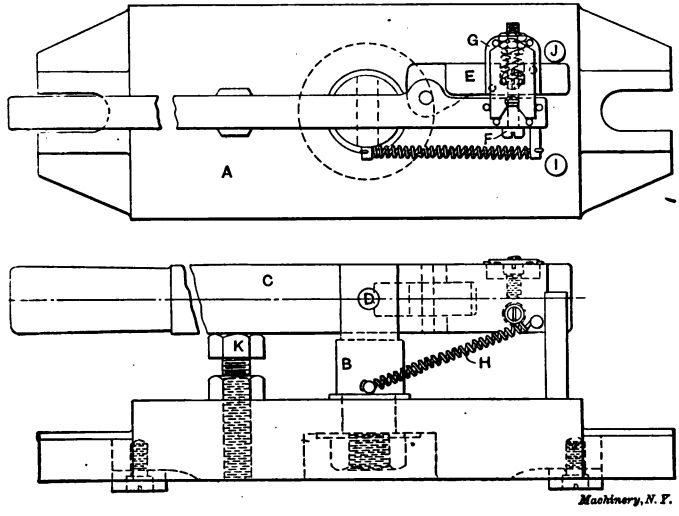


Fig. 52. Slotting Fixture for Hand Miller.

being slotted. The rings are held and located on the holders *C* and *D* by screws and dowel pins not shown in the cut. Holder *D* is driven by means of a belt from the countershaft to grooved pulley *E* and through spur gears *F* and *G* and worm and worm-wheel *H* and *J*. Holder *D* is made in one piece with the worm-wheel shaft. Holder *C* is in turn driven by holder *D* by means of pins *K*, held in holder *D*. Spring *L* takes care of any variation which may exist in the size of the pieces being slotted.

To locate and drill the holes, which retain the work, in rings *A* and *B*, they are screwed and doweled on the holders, and the fixture placed on a drill press in such a manner that an equal section of the hole will be drilled in each ring. The rings are then case-hardened. For different pieces of work it is merely necessary to make different rings to suit the conditions of the piece. The bracket *M* is adjustable forward and backward to allow different thicknesses of rings to be

* S. A. McDonald, November, 1907.

used. The hole in bracket *M* is bored at an angle of 2 degrees, and the plate *A* is also faced off at the same angle, so that it will be parallel to ring *B* at *N*. By boring the hole at an angle, it will be readily seen that at the point *O* the space between the two rings is the greatest, and at point *N* the least. In operating the fixture, it is placed on the milling machine so that the slotting saw will pass directly through the center of the screw head to be slotted, and directly over the center of the rings. The fixture is then started, and the operator only inserts the work in the holes. As will be seen, the piece is gripped firmly while passing under the saw, and automatically dropped when reaching the bottom.*

Fixture for Splitting Work in Two Parts.

Sometimes a simple operation like splitting a piece of work in two will be found to present difficulties equal to those encountered in much more complicated operations. One such a case was met with in machining the pieces shown in Fig. 54, which were to be split in two along the line *X-X*. Owing to the peculiar shape of these pieces it was impossible to clamp them, by simple means, in any position so as to mill more than a single one at a time, and as a large quantity were to be made it was desirable to arrange so as to cut a number at a single operation. For this purpose the fixture shown in Fig. 55 was constructed and with this ten pieces could be cut at a single setting.

This fixture consisted of a casting *A* which was provided with a tongue for aligning it upon a milling machine table, and a slot at either end for receiving a clamping bolt. A series of holes, of the same size as that in the work, was drilled in the upper part of the fixture, and to insure their being parallel with the tongue, the drilling was done in place upon the milling machine, the vertical attachment being used. These holes were fitted with the studs *B*, which were of sufficient length to extend through the work *C*, as shown in the section. On the bottom of each stud was placed a split washer and nut, the latter being small enough to pass through the hole in the jig and work. These studs were prevented from turning when the nut was tightened, by means of a set-screw *D*, the point of which fitted a slot in the side of the stud. A similar slot was also cut in the side of the nut so that it could pass the setscrew. A slot *E*, the width of the splitting saw, was cut through the top of each stud, and the set-screw *D* insured this slot being always in proper position for the saw to pass through when splitting the work.

Before the pieces were placed in the jig, they were bored and faced on the top, bottom and on the straight sides, so that the splitting formed the last operation. Ten of the pieces were placed on the fixture, the bolts *B* put through and the washers put in place. Before tightening the nuts a straightedge was placed along the front side of the pieces so as to set them all squarely, after which the nuts were tightened and the saw passed through the group in the usual manner.**

* Fred R. Carstensen, September, 1907.
** Charles P. Thiel, August, 1903.

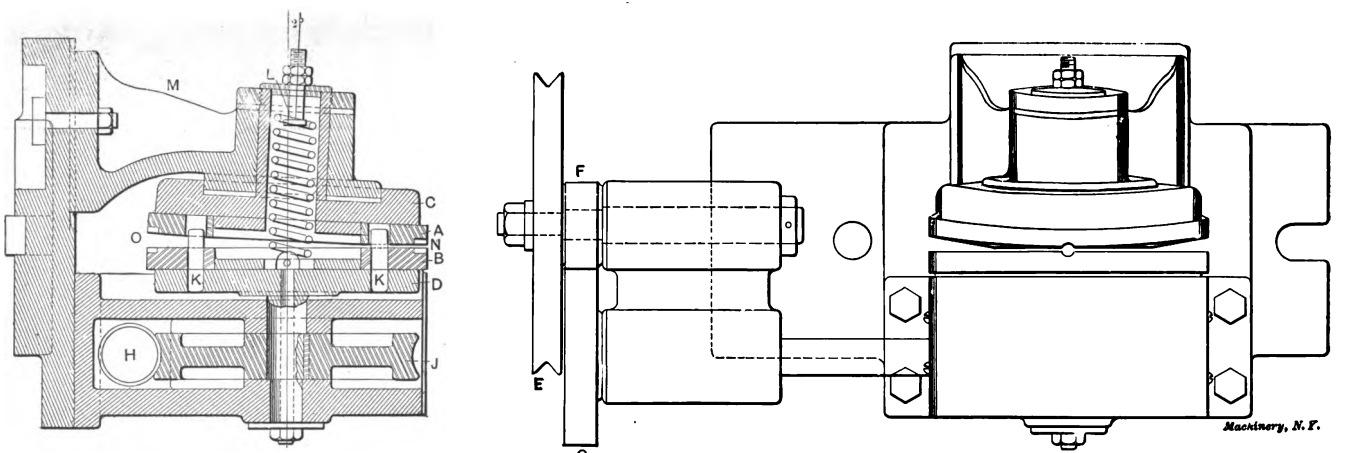


Fig. 53. Screw Slotting Fixture for Continuous Operation.

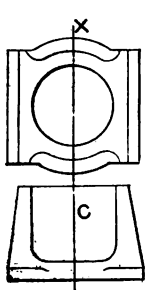


Fig. 54. Piece to be Split in Two.

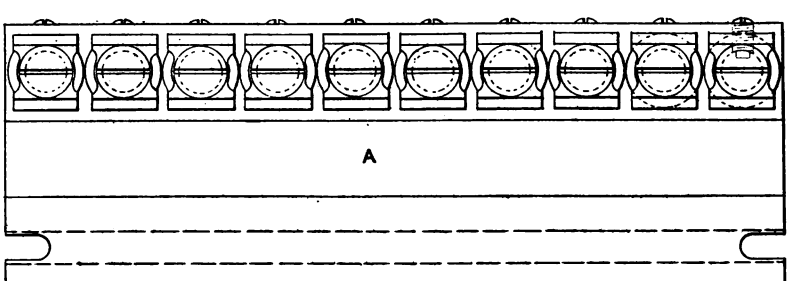
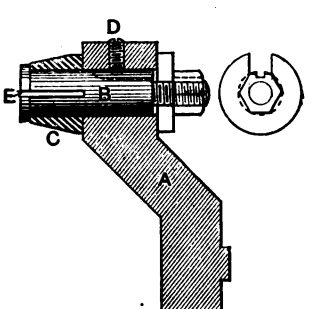


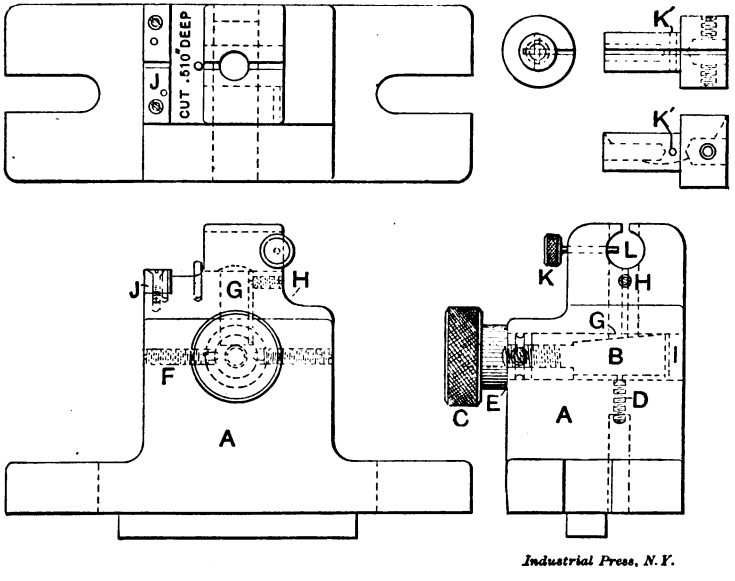
Fig. 55. Fixtuse for Splitting Ten Pieces at a Time.



Slotting Fixture for Special Chuck.

The piece shown in the upper right-hand corner of Fig. 56 is a latch chuck, made of cold rolled steel, and used on a special machine for holding the ends of rods. The body and the center holes on both ends are turned in the lathe and the other holes are drilled in a special jig.

The fixture shown in Fig. 56 was designed for holding the chuck while milling the longitudinal slot to receive the latch, which was required to be exactly central with the axis of the piece. While not of unusual design, it possesses some advantages that make it especially useful when it is necessary to perform milling operations of this nature. It is so made as to be free from any outside incumbrances, and the parts where wear is likely to become appreciable are hard-



Industrial Press, N.Y.

Fig. 56. Slotting Fixture for a Special Chuck.

ened. The principle applied to the clamping mechanism is that of a gradual wedging action, thereby holding the work securely, and at the same time permitting the quick removal of one piece and the insertion of another by simply turning the knurled knob to the right or left as may be desired. As will be seen, the clamping mechanism is entirely enclosed, thus avoiding dust and dirt, and lessening the liability to accident from any external cause. While the illustration shows only one way in which this device may be employed, a wider field of application will without doubt suggest itself, as it is suitable for holding all kinds of milling jobs, especially where the work is polished and would be marred by clamping in a vise in the ordinary manner.

The fixture is made of liberal proportions, to insure rigidity, and is tongued and slotted for clamping bolts. Through the center of the

body of the fixture is drilled a hole carrying the tightening clamp *B*, the larger diameter of which fits snugly in the hole while the neck is turned down and threaded to fit the clamping knob *C*. To prevent the piece from turning, when the knob is turned, a groove is cut the entire length of the larger diameter, and into this fits the point of the setscrew *D*. The upper face of *B* is milled flat on a taper of one inch per foot and this part of the piece is made very hard. When clamping the work, the shoulder of the knob brings up against the body of the jig at *E;* on reversing, the two screws *F*, with their points seated in a rounded groove in the knob, prevent it from being withdrawn.

The semi-circular faced plug *G* stands vertically in the position shown, one end resting on the inclined face of *B* and the other bored out to conform to the diameter of the work. A spline is cut on one side to receive the point of the screw *H* which, while permitting a free movement up and down, checks any tendency for the piece to rotate. This plug fits the hole so freely that when it is released it falls away from the work by gravity. When the parts of the fixture are assembled the chamber in which the slide *B* is located is filled with vaseline and the plug *I* driven in, thereby completely enclosing the mechanism and preventing the ingress of grit or the escape of the lubricant.

The milling of the slot in the work is performed with an ordinary metal saw of the required width; setting it central is simplified and facilitated by the set gage *J*, which is of tool steel, hardened and fastened in place with screws and dowel pins. The depth to be cut is measured by the graduated dial on the milling machine. In this case it is 0.510 inch, and this is stamped upon the fixture for convenience of future reference. To operate the fixture, the pin *K* is withdrawn a sufficient amount to clear the hole *L*, and the nose of the chuck to be milled is inserted against the stop pin. The chuck is rotated by hand, at the same time pressing upon the head of the pin *K*, until the pin slips into the fulcrum pin hole for the latch, *K'*, that has been previously drilled in the work. A turn of the knob *C* then clamps it tightly for the milling operation.*

Fixture for Plain Milling.

While plain milling operations seem very simple to the casual observer, it is often a perplexing problem to so arrange and systematize these operations, when several surfaces are to be finished on the same piece of work, that the required accuracy is combined with a reasonable degree of speed of carrying out the work. In Fig. 57 is shown a fixture of very simple design for milling pieces in duplicate, where several faces are surfaced. This fixture reduces the setting of the machine and handling of the work to a minimum.

Let *A* represent a piece to be surfaced on spots shown on the sides and ends, these surfaces to bear definite relations to one another. It is quite possible to put spotting pieces on top or bottom and finish these first, fasten the work to the table and finish one side, and then, by parallels and squaring plates, finish the other surfaces from the

* C. H. Rowe, October, 1903.

first. But this means a good many measurements, bolts, straps and settings of the machine, the mass of which may be avoided by the fixture shown. It consists of a casting *B* to which the work is fastened in any convenient way after being located by the spots *e e'*, *s s* and *s' s'*, which are finished to the dimensions of the finished work, and serve to show the necessary position of the work in order to clean. The fixture has on its lower side a key slot *k* corresponding to the slot in the machine platen and spaced equally between the opposite spots *s s* and *s' s'* on the side.

In setting up the machine, the fixture is located by the key, and the cross-feed screw is used to bring the spots *s s* or *s' s'* to the line of cut of a face mill on the spindle nose. As the slot *k* is located centrally

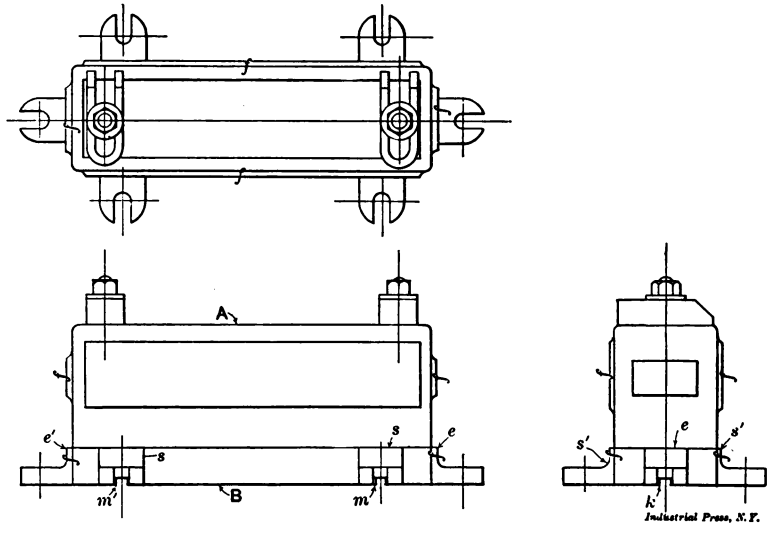


Fig. 57. Time-saving Fixture for Plain Milling.

between the sides to be milled, the same setting of the machine answers for both sides, it being necessary only to turn the fixture around. The ends are placed in position in the same way, and without altering the setting of the machine, for the slots *m m'* near the ends of the fixture are the same distance from surfaces *e e'* as is slot *k* from surfaces *s s* and *s' s'*. Therefore, the operator has simply to see that the key enters the slot properly.

Ears may be provided for receiving the bolts which, when loosened, may simply be moved to suit the new position of the fixture as it is swung around. In practice one side may be milled first and then one end, the other side, and the other end; one rotation completing the piece. On many kinds of work the key and slots would not be accurate enough, in which case a base plate upon which the fixture might be located by dowels could be brought into service. The principle, however, would remain the same.

Fixture for Hollow Milling.

Hollow milling operations should more strictly be considered as drilling operations. The fixtures used for hollow milling usually resemble drill jigs more than regular milling fixtures. The work is often carried out on a drill press, rather than in a milling machine. Being, however, by its name classified as a milling operation, a fixture used for hollow milling has been selected in order to make the present collection of typical milling fixtures complete. This fixture is shown in Fig. 59, and the work on which it is used is shown in Fig. 58. The surfaces *D*, *E*, *F*, and *G*, of the arm shown in Fig. 58 have been finished as a first operation, but on the other end of the arm is a boss on which the surfaces *A* and *B*, and the hole *C* must be finished true in relation to *D*, *E*, *F*, and *G*, and at a certain distance from them.

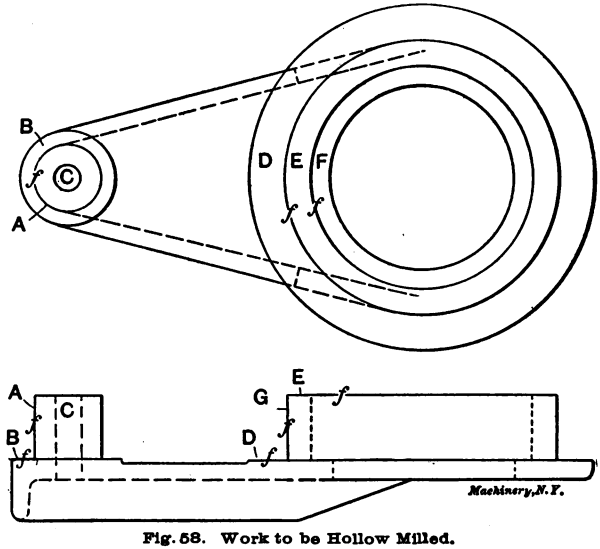


Fig. 58. Work to be Hollow Milled.

This last operation on these arms had always been done on the face-plate of an engine lathe, but a lathe of large swing, and therefore of heavy construction, was necessary, and as the diameter of the boss had to come within a limit of 0.001 inch, the lathe was inconvenient and the time unsatisfactory. To obviate the necessity of swinging the piece in the lathe, a suitable "built-up" hollow mill, and the fixture shown in three views, Fig. 59, were designed. With these appliances, the work was done in the drill-press with a reduction of 50 per cent in time over the old method. Moreover, not as highly skilled labor was required to do the work.

The fixture for holding the arm consists of a body *G* which carries the hardened bushing *H* for guiding the mill. At the opposite end and on the under side a boss is turned to fit the surfaces *E* and *F* on the arm. This boss is for locating the arm in the proper position, the

arm being clamped by means of the bolt *I*, the split strap *J* and the nut *K*. The bolt *I* is prevented from turning by the headless screw *h*. The set-screw and check-nut *O* are used for locating the end of the arm sideways. The hook-bolt *L* and knurled nut *M* are used to resist the pressure of the mill when cutting.*

Adjustable Milling Fixtures.

Often, when a number of different sizes of some work, shaped and finished in the same or similar ways, are to be milled, it is possible to make milling fixtures, which with slight modifications and adjustments may serve for all the various sizes of the work, saving the expense of a great number of different fixtures. Such fixtures may be termed adjustable milling fixtures. They can often be made in a very simple manner.

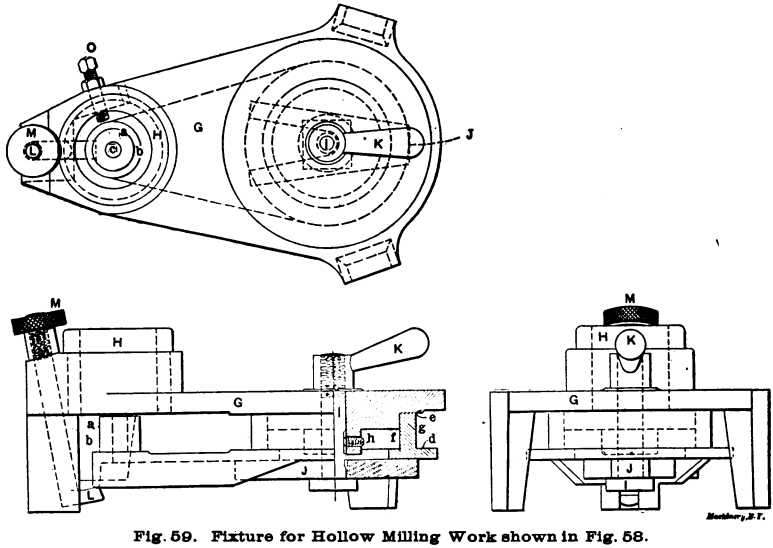


Fig. 59. Fixture for Hollow Milling Work shown in Fig. 58.

The casting shown in Fig. 60 strapped to the table of a milling machine is one of a large variety of housings of widely varying shapes and sizes, which are used in the construction of a certain automatic machine. These housings resemble each other in that they are provided with a V-groove at the bottom, where they are clamped to the bed of the machine, and also in the fact that they are made with various pads and bosses, similar on both sides, which have to be milled off to a uniform thickness of 1½ inch. The cross-sectioning in the plan view distinguishes the finished areas. The large number of patterns used would have made the job of providing a separate fixture for each style of casting a very costly proceeding. Therefore the following sectional fixture was made, and has proved to work well on all the different pieces on which it has been tried.

* Charles Thiel, January, 1906.

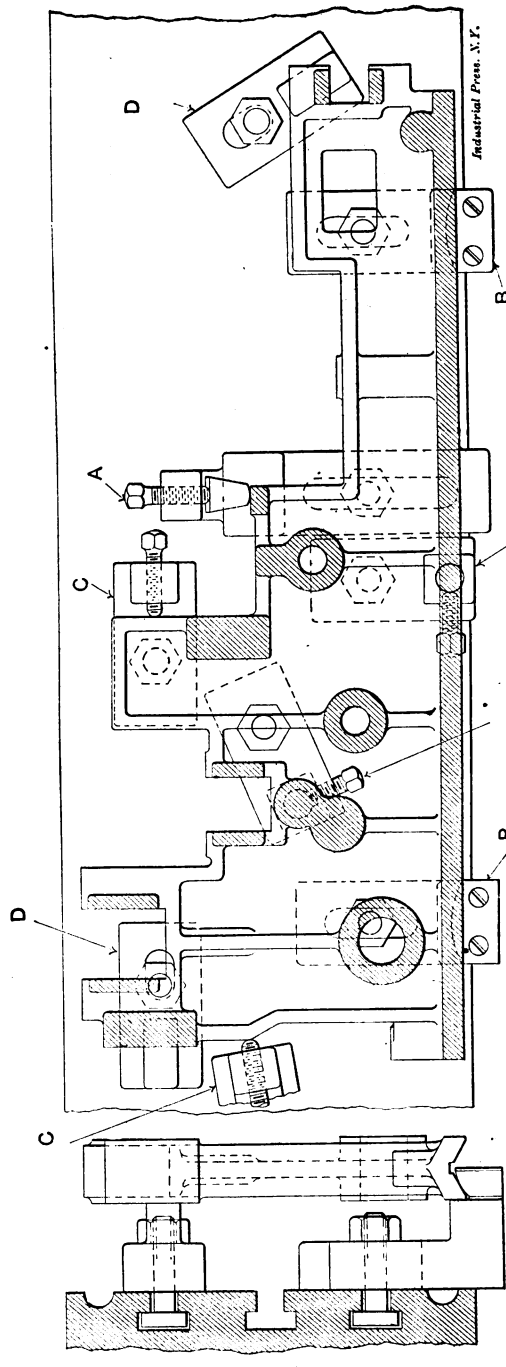


Fig. 60. Adjustable Fixture for Holding a Machine Housing on the Milling Machine Table.

Fig. 61 shows the different parts of the fixture in detail: *A* is a block with a setscrew and spur, similar to that used on a planer; *B* is an abutment provided with a steel block to enter and hold down the V-groove edge of the casting; *C* is a simple stop to take the thrust of the cut; *D* is a wedge used under springy places in the casting; and *E* is a spring-jack used where convenient for a similar purpose. In Fig. 60 a typical casting is shown on the milling machine platen with the various holding pieces arranged about it. The two blocks *B* are placed at the outside edge of the table, and the work is supported on

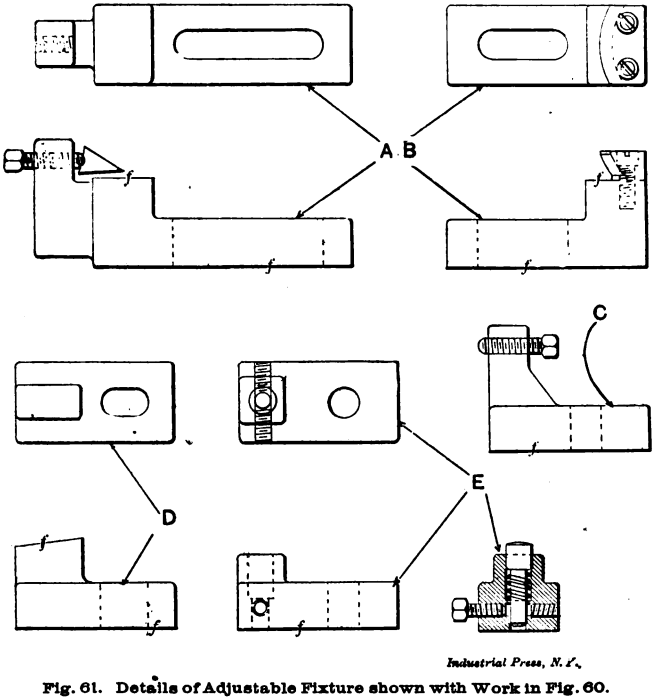


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Fig. 61. Details of Adjustable Fixture shown with Work in Fig. 60.

these and the spur block *A*, thus giving a three-point bearing for a foundation. The spur holds it down on one side, and the steel blocks in the V-groove hold it down on the other. Blocks *C* with their set-screws are arranged as shown to take up the end thrust in each direction, and wedges *D* are slipped lightly into contact with outlying corners of the work where support is needed. Spring-jacks *E* are also located where the work is most liable to spring under the influence of the mill. These jacks are fastened permanently in place, the set-screws loosened, then the work is pressed down into place and fastened with the spur block *A*. The set-screw, which bears against the teat of the spring plug, is then clamped, and the casting is thus supported without the possibility of the casting being sprung as it would be if fastened down onto a solid bearing which might or might not be

of the right height. The set-screw may be placed in either side, as convenient, as shown in detail of spring jack in Fig. 61.

A 6-inch end-mill is used in the vertical milling attachment to make the surfacing cut. This does its work more rapidly and with less pressure than a cylindrical cutter would. Care is taken to feed in such a direction that the thrust of the cut will be toward the V-blocks *B* or the stops *C*, although when once by mistake the cutter was run toward the spur *A*, this seemingly insecure fastening device held the work well. These housings are allowed a limit of 0.002 inch over or under the standard thickness of 1½ inch.*

Gang Milling Fixtures.

In the manufacturing of small interchangeable castings for machine parts, gang milling fixtures play a very important part. When the parts are machined to extremely accurate dimensions, and are produced under the modern piece-work system, the object sought is to

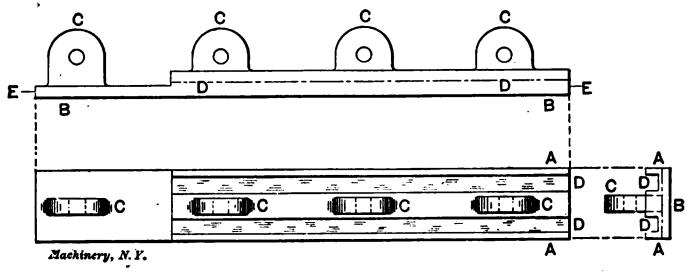

Fig. 62. Casting Milled in Fixture shown in Figs 63 to 66.

handle as many castings at a time as possible, in fixtures so designed as to insure the complete interchangeability of the product. To illustrate the value of gang milling fixtures for manufacturing accurately machined duplicate parts, and also how a number of such parts may be handled and machined expeditiously at the minimum of cost, a gang milling fixture which is in use in an establishment requiring over 100,000 of the castings machined in this fixture per year, has been described in the following.

In Fig. 62 we have three views of the casting machined in the fixture. The work performed is the milling of the two channels indicated by *D*. Previous to this operation the casting is machined on the back *B* and also on the sides and ends *A* and *E* to limit gage measurements. Subsequent to the operation, the four holes are drilled in the projecting lugs *C*, the insides of the channels being utilized as banking or abutment surfaces for the locating of the castings in the drilling jig. Figs. 63 and 64 are two views of the fixture complete, Fig. 63 being the plan view, which shows the appearance of the fixture without the work in it, and Fig. 64 a vertical cross-sectional view. Fig. 65 is a longitudinal sectional view of the fixture, and also of the gang of ten cutters used in conjunction with it. *Y* represents the cutters; *X*

* Ralph E. Flanders, October, 1904.

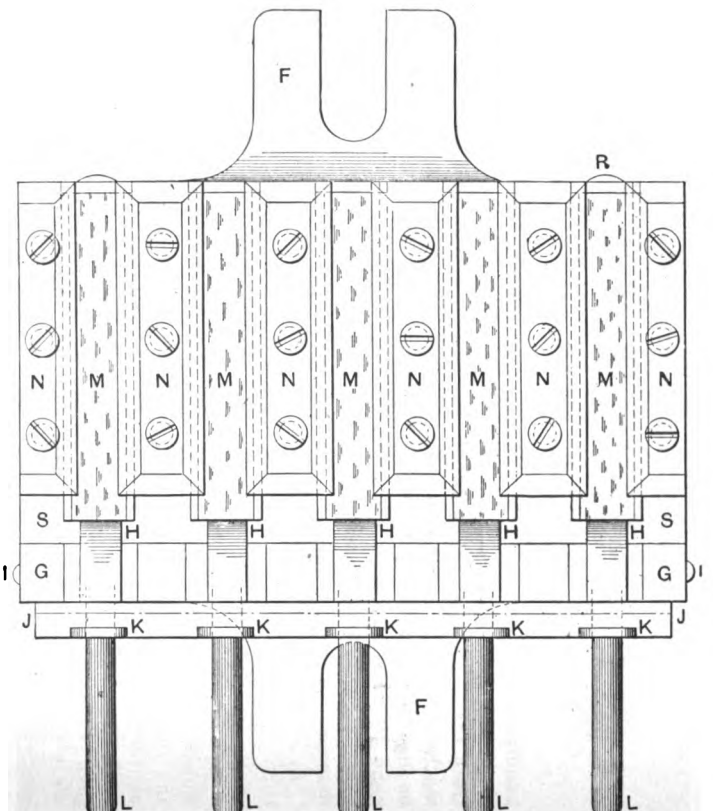

Fig. 63. Plan of Fixture for Milling Work shown in Fig. 62.

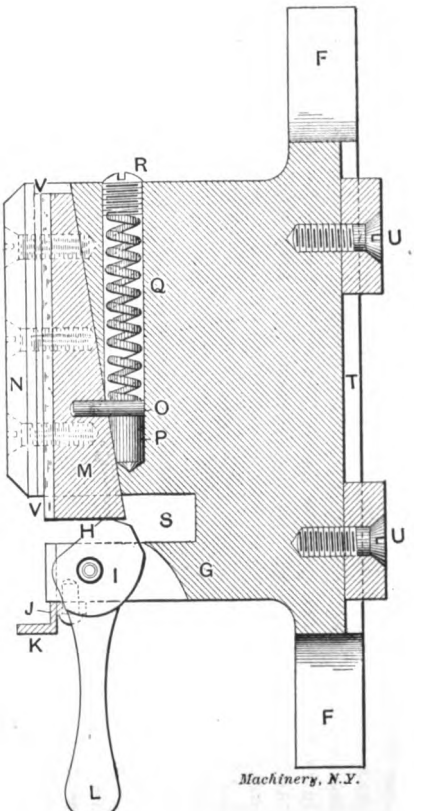

Fig. 64. Vertical Cross-section of Fixture.

represents the washers or collars; and *W* represents the milling machine spindle. Fig. 66 is an end view illustrating the fixture with the work in position and presented to the cutters for milling.

The fixture handles five castings at a time. The body casting has projections or wings *F*, at two sides, and has two locating tongues at *U*, for fastening and locating it on the table. The body casting has five inclined channels milled in its face to accommodate the five hardened tool steel work locators *M*. The five parts *N* are also of tool steel, hardened and tempered, and fastened to the wall surfaces between the inclined channels by means of three flat-headed screws each.

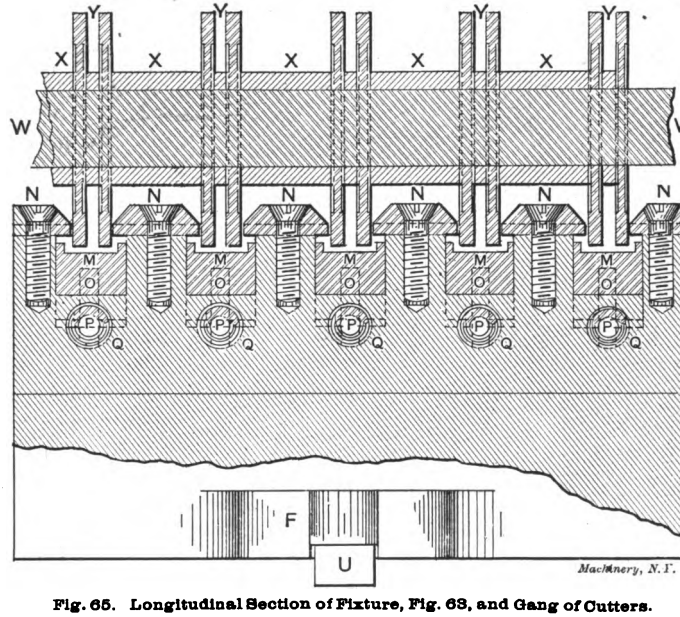

Fig. 65. Longitudinal Section of Fixture, Fig. 63, and Gang of Cutters.

These pieces serve as banking pieces or surfaces for the work to clamp up against. Five eccentric levers *L* force the work locators up the inclined ways, thus clamping the work in position against the plates *N*. These levers are fastened in milled slots by means of the drill-rod shaft *I*. The eccentric portions of the levers are indicated clearly at *H* in Figs. 64 and 66. *J* is a stop bracket fastened to the back of the fixture or body casting by means of several round head screws. The portions at *K* are stops against which the ends of the castings to be machined, abut. The construction for forcing the work holders back in the inclined channels upon the releasing of the eccentric clamping levers *L*, thus allowing of the removal of the work, is shown in the vertical sectional view, Fig. 64. It consists of a stiff spiral spring *Q*, located in the drilled hole *P*, a pin *O* for engaging this spring, and the headless set-screw *R*. One end of the spiral spring rests against the screw *R*, and the other against the pin *O*. The tension is

kept sufficiently stiff to cause the work-holders to release the work immediately upon the lever *L* being pulled upward; each of the five work holders is equipped with such an arrangement.

When in use, the fixture is clamped to the table of a large universal miller, and this is then adjusted until the work receivers or holders are in the relative positions to the cutters illustrated in Figs. 65 and 66. The castings are located in the holders; the eccentric levers are pushed downward, as shown in Fig. 66; and the castings are thus

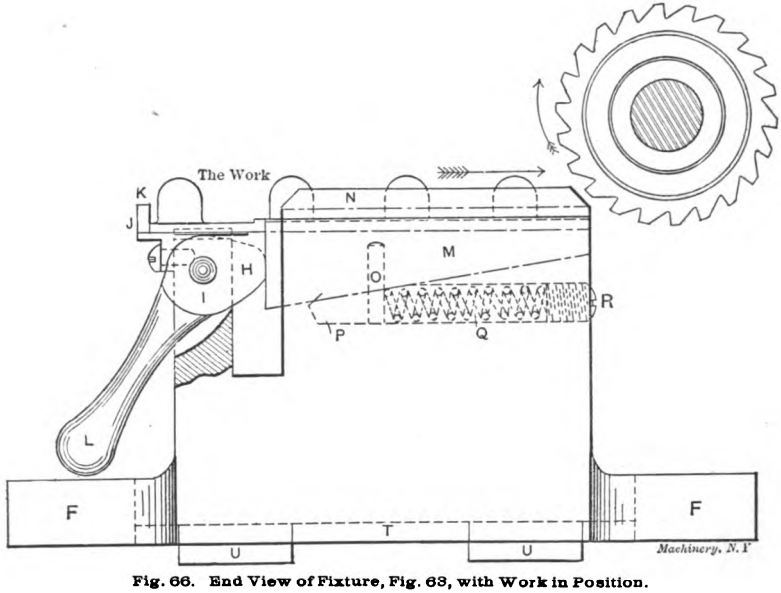

Fig. 66. End View of Fixture, Fig. 63, with Work in Position.

clamped in position. The feed is then thrown in and the table and fixture travel forward until the channels *D* are milled. The table is then fed backward and the machined work removed.*

Fixtures for Milling a Journal Cap and Base Plate.

Simplicity in jig and fixture design is one of the most important fundamental principles. It is not necessary that a fixture be elaborate to be efficient. On the contrary, it is often the case that the simpler fixture is by far the one to prefer, as it has less parts to repair, and, when repairs are needed, they can be carried out with less trouble. The following description of tools used in the milling machine for finishing a journal cap and base casting, gives a few instructive examples of simplicity in fixture design coupled with efficiency.

Taking the cap first, we may hold it in the manner indicated in Fig. 67. If we are manufacturing a large number of these pieces it will pay to make special fixtures for arranging them so that the extreme length of the table feed or travel may be used. We may arrange to

* Joseph V. Woodworth, July, 1905.

take one or more rows of the castings side by side, depending on the size of the miller. The cap will be seen to be resting on pins where the bosses for the cap bolts come, this making a convenient and reliable foundation. The cap is held sideways by the set-screws on either side and is held down on the pins by the clamp shown in the sectional view. The cut explains itself, so that but few words are necessary in connection therewith. In the holding of work on the milling machine table or in supplementary fixtures it seems to have become the idea that it is necessary to bolt it down with all the force that it is possible to use without stripping the thread on the bolts. So much strain is not necessary, serving as it does only to distort the table, making it run hard and eventually producing a permanent set

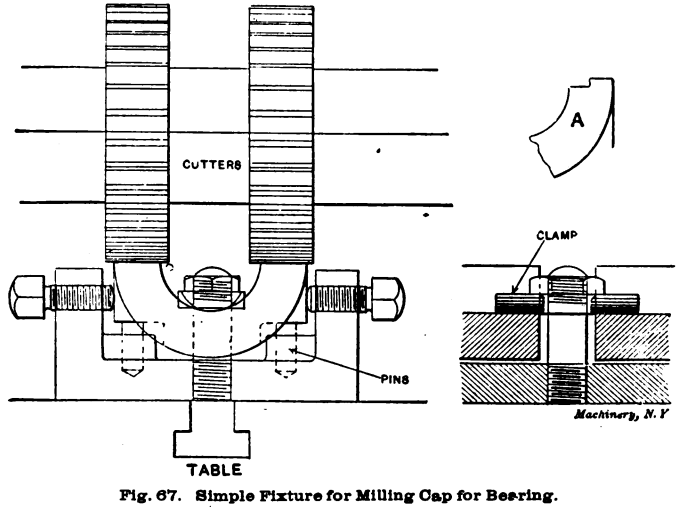

Fig. 67. Simple Fixture for Milling Cap for Bearing.

which gives the working surface an untrue face. This straining of the binder bolts also wedges the T-slots out of shape, peening the metal above the T so as to project above the rest of the surface. An examination of the machine in operation will show that in 90 per cent of the work done the force or pressure of the cut is symmetrical and has but little effect on the work, all the holding required being merely that necessary to keep it from sliding either along in front of the cutter or sideways. This is accomplished by bunters and toe clamps. Of course it is necessary that the work be held down on the table, but very little power is necessary in doing so. If the cap is made with the matched fit shown at *A* instead of with straight fit, the advantage of milling over planing such classes of work is very apparent, as gang cutters will then finish the work at one setting, while the planer will require at least two settings. But the real gain would be in obtaining interchangeable work which can be obtained on the planer only at the expense of considerable time and trouble, but which is a matter of course on the miller.

In performing the corresponding operation on the base casting we have the advantage of the broad base and the projecting surfaces for clamping which make it an easy matter to set and hold the work. The same that has been said regarding the operations on the cap may be applied to the base. Fig. 68 shows how this piece would be held. The

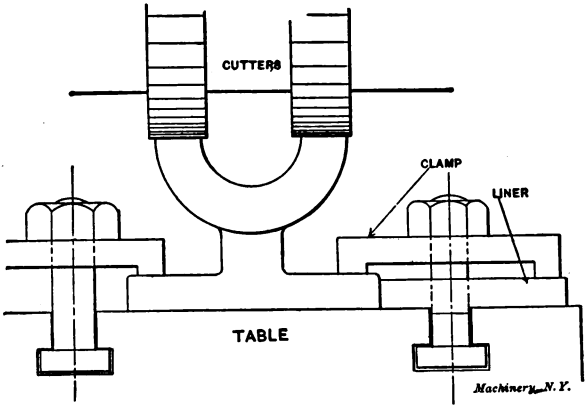

Fig. 68. Holding the Base of Bearing while Milling Seat for Cap.

clamps hold down the piece, while the piece is blocked up against a liner to insure a setting parallel with the travel of the table. The row is kept from shifting endwise by using the bunters mentioned above. In machining the foot of the base piece we are confronted by a job

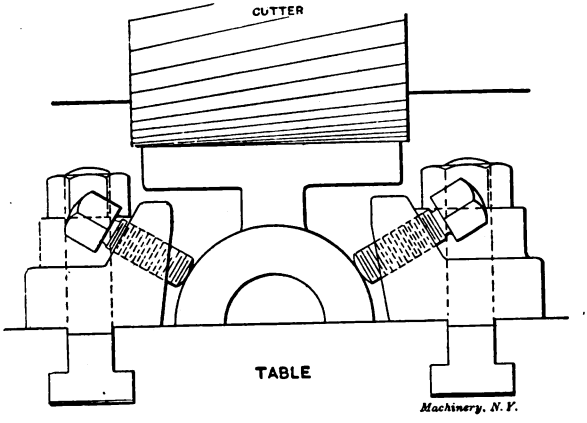

Fig. 69. Simple Holding Device used when Slab Milling the Lower Surface of the Base.

that presents a kind of milling operation which has many little points of interest. The problem of milling comparatively broad surfaces is presented. It is an acknowledged fact that the milling of such surfaces must be accomplished by cutters that are so constructed that the chip

is broken up into short cuts, giving the operation the advantage of the single pointed tool in the question of power required, and truth of surface obtained. This is accomplished by notching the teeth of the cutter so that they may be presented to the work successively, both notches and teeth being cut spiral at right angles with each other. A surface produced by such a cutter will bear the strictest examinations as to truth.

Fig. 69 shows one method of machining the bottom surface. In this method we use a plain milling cutter as shown, taking one or two cuts as the case may require. If very little stock has to be removed but one cut ought to be sufficient, as the resulting surface will be good enough for the intended purpose. As will be seen the piece is held

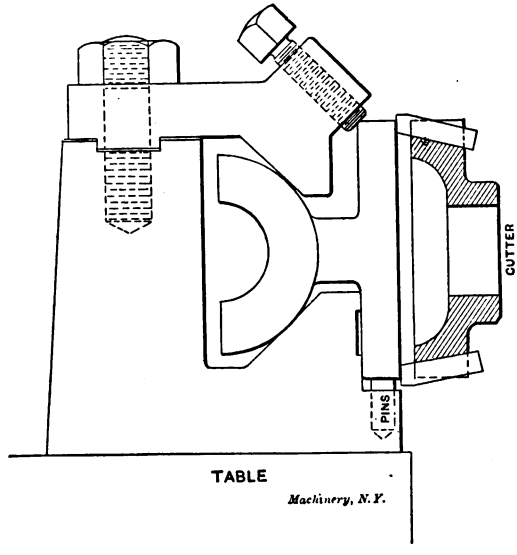

Fig. 70. Alternative Method of Holding the Base when Milling the Lower Surface.

down and prevented from moving sideways by the screws which are tapped through the strips bolted to the table. This makes a convenient method and one that will be found to answer the purpose very well. Another method of performing the operation is by the use of an end mill as shown in Fig. 70. This means of removing the metal is very efficient, as a very true surface can be obtained with a much faster feed and deeper cut than can be done by slab milling. The power necessary to revolve the cutter and force the feed is also very much less than that used for slab milling. While the surface may be badly marked it will yet be almost absolutely true. When the work is set up on the edge as shown, no trouble is encountered with the chips as is otherwise the case. We are fortunate in finding this piece to be a very easy one to provide jigs for, as it permits itself to be set in almost any position. The method used in Fig. 70 is a good one, and will be

found very convenient. The top clamp is removed when the work has to be removed or placed in position. This clamp serves the double purpose of holding the work and of setting it in line, the screw being used to make any allowance for variations in the castings. When this method is chosen the machining of the bottom should be done before the cap bearing is milled, as this gives a good solid setting for the latter operation. A great many operations may be accomplished by this latter method which are now milled with plain cutters. The action of the cutter in this operation closely resembles that of the single pointed tool and has all the advantages that are claimed for this tool, but very few of the disadvantages, it being a multiple cutter, which means greater output.

The last four cuts shown leave considerable to the imagination, as they show but an end view of the work. This is done because the same method may be used to advantage in holding one or a dozen pieces. Elaboration on the above does not seem necessary, since the principle is shown.*

* John Edgar, November, 1906.

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